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MICROFORM DISPLAY PARAMETERS AND SYSTEMS IN THE SHIPBOARD ENVIRONMENT

Prepared for the

Naval Research Laboratory

Washington, D. C.

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March 1971

PSYTRONICS, Inc.
FAIRFAX, VIRGINIA 22030

MICROFORM DISPLAY PARAMETERS AND SYSTEMS IN THE SHIPBOARD ENVIRONMENT

I. Empirical Investigation of Display Legibility

II. Survey of Available Microform Equipment

III. Potential Shipboard Applications

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FOREWORD

This study effort was conducted under the technical direction of the Naval Research Laboratory (Code 4020) under sponsorship of the Naval Orcnance Systems Command (ORD-03).

Products or services discussed in this report are included as illustrative examples and no endorsement, either positive or negative, is intended.

Conclusions drawn are those of the authors and are not represented to be the views of the Government.

EXECUTIVE SUMMARY

This study was concerned with potential applications for microform in the shipboard environment. The first phase was comprised of two experiments to determine the effect of various parameters on the legibility of rear-projected displays. The parameters were image resolution, size, brightness, color, ambient light, and frequency and amplitude of ambient vibration.

The results indicated that image resolution was a critical factor in legibility, followed by image brightness and size. Image vibration amplitude of 1/8-inch over the range of 0 to 30 Hz degraded legibility to a small but measureable degree while 1/4-inch amplitude rendered the display illegible for all practical purposes. Display color (red vs. white) had no effect on legibility for displays of equal brightness. Image polarity (positive vs. negative) also had no effect on legibility. The parameters tested interacted in a complex manner indicating that all factors must be considered together in selecting or designing equipment for a given application . Tables 8 through 11, beginning on page 60, show relative performance coefficients for various parametric combinations. The coefficients are proportions of reading speed and accuracy relative to reading hand-held typewritten copy under good lighting conditions.

The following features are recommended for microform viewers intended for shipboard use:

(1) Maximum screen brightness of at least 80 ft-L;

(2) Continuous brightness adjustment control from zero to maximum screen brightness;

(3) Non-glare type viewing screen;

(4) Focus controls which are not overly sensitive;

(5) Provisions for protection of the viewing screen from extraneous light/glare sources such as a shield or curtain arrangement;

(6) Provision for use of a red filter for operating under red-light conditions. Brightness adjustment or installation of the red filter should not require the user to view an illuminated projection lamp or other brightly illuminated element of the system;

(7) Readers to be used under red-light conditions should be light-tight, i.e., no light leaks;

(8) Controls and contours should be designed to minimize sharp edges, corners, and projections which may injure a user upon impact (such impact could occur during high speed maneuvers or in rough waters);

(9) Microform equipment should be isolated from ambient ship vibration to preclude degradation of image legibility. Small amplitude vibration may be amplified in the optical system to produce image vibration of as much as 1/4-inch.

The second phase of the study (p. 71) was a survey of available microform readers, reader-printers, camera and film processing equipment, and information retrieval systems. Major U.S. and foreign manufacturers were surveyed. Microform devices ranging from simple portable viewers costing only a few dollars to sophisticated, fully automatic retrieval systems employing video dissemination. Cost of the latter per system is in the $100,000 to $200,000 range.

The third and final phase (p. 142) describes the kinds of information used in different departments of various types of ships, the current format of the information, and an appropriate type of microform to which each kind of information could be converted. Regarding potential microform applications aboard ship, the following conclusions and recommendations are made:

(1) The current volume and use of hard copy aboard ships would appear amenable to conversion to microform (micromation) in many areas;

(2) With proper study, it should be possible to justify micromation in terms of cost, operating efficiency, and increased file security;

(3) Current microform technology provides a range of equipment and capabilities which can be readily matched to user requirements from carrier type ships on down;

(4) Microform affords specific advantages in the area of document security and anticompromise measures.

ACKNOWLEDGMENTS

The valuable contributions of the following individuals to this research effort are gratefully acknowledged: Mr. James Reynolds, Special Studies Group, Naval Research Laboratory; Mr. Ed Remen, Northern Virginia Community College; and Mr. Tom Latterner, Control Data Corporation.

Appreciation is expressed to those manufacturers who so generously cooperated with their time and information in the second phase of the study.

Finally, sincere thanks are due to S. H. Reilly and R. A. Linehan of Psytronics, Inc., whose efforts played a major part in whatever success this effort may enjoy.

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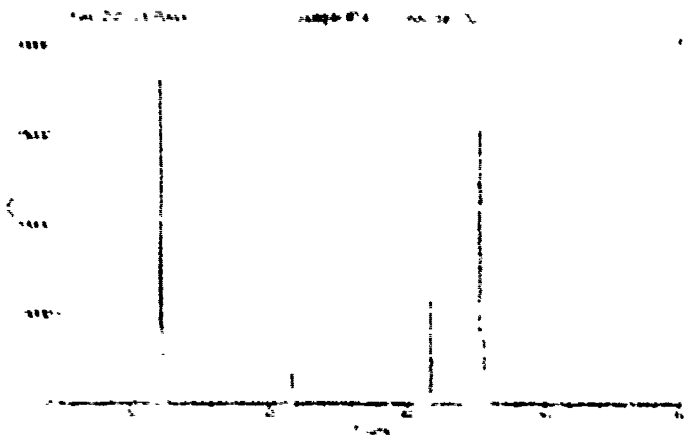

Figure 8 X-ray diffraction θ-2θ scan of a PLMNT film by MOCVD on c-sapphire

Figure 9 shows the electro-optical measurement result of a recently developed PLMNT film sample. In order to have a comparable value for evaluating materials, the average slope at small positive field was used to calculate the effective linear EO coefficient R (pm/V). For this sample, the EO coefficient was measured to be 353pm/V, which is already 18 times higher than $LiNbO_3$ at low frequencies. BATi will continue to improve these EO films for this and other applications.

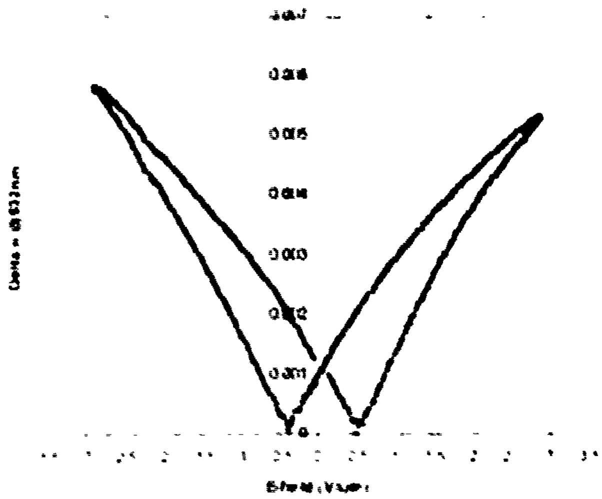

Figure 9 Electro-optic loop of a recently developed PLMNT film

Instrument for uniformity measurement of EO layer

For future development of this technology, especially for imaging application, the spectral response has to be very uniform (such as 0.2 %) within the entire aperture. One major issue controlling the uniformity is the material uniformity of the EO layers. We are developing a metrology method to measure the uniformity with nanometers accuracy, which is the phase-shifting white light interferometer. The white-light polarization interferometer is based on

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INTRODUCTION

The information explosion of the past three decades has made storage and retrieval a critical problem in industry, education, and the military. For the Navy, the problem is amplified because of time, space, and weight constraints aboard ship. In routine and combat situations, information flow is the life blood of our modern systems. The bulk paper medium seems no longer consistent with the speed and complexity of the systems it is intended to support. Large volumes of printed matter, e.g., reports, manuals, books, diagrams, engineering drawings, etc., are difficult and inefficient to file and retrieve. Furthermore, in military operations, there is the need for the safe handling of classified information, and at times, the necessity for rapid and thorough destruction of classified materials to prevent their compromise.

One approach to the problem which appears to hold much promise is conversion to microform systems. Bulk is reduced by more than 90 percent; production and dissemination of information on film is considerably faster and less costly than paper; storage and retrieval is fast, accurate, and can be fully automatic if so desired. Certain modern microform retrieval systems permit random access to any given document. Also, the files may be browsed using one or more descriptors. These systems can do many things as well or better than a computer and at considerably less cost. Using a computer as a filing system and printing press is often inappropriate and expensive.

For many businesses and institutions, there appears to be every reason to convert to microform. For certain other applications, e.g., aboard ship, a range of factors must be carefully considered before decisions in this regard can be made. First, one would have to specify or analyze user requirements in the operational setting. Next should be a survey of available equipment and microform systems. This equipment would have to be evaluated with respect to its ability to meet user requirements and to function well in designated operational environments. Cost effectiveness would be an

important factor and would include not only the cost of the equipment but the entire conversion process which requires organizing, coding, and updating the information to be handled by the microform system.

Depending upon the particular application, general purpose equipment may be found to be adequate. Or, there may be the need for development of a dedicated system, one tailored to specific user needs and functions.

A total systems approach to a problem such as this, while highly desirable, is not always possible because of financial and time constraints. It is possible, however, to make an effective start by addressing certain fundamental aspects of the problem which will provide a foundation for further work. This was the orientation of the present study.

In reviewing the technical and trade literature in the microform field, it became apparent that there is the need for basic human engineering data which would aid in the design or selection of items of equipment. This need is aptly described by one expert in the field (Teplitz, 1970) as follows:

"Even though microfilm has been available for almost 40 years, it is just now coming into its own, being accepted on a broad enough basis to provide a large market for equipment manufacturers, thus making new equipment design feasible. The number of microfiche users is increasing to the point that careful human factors studies of the critical limitations and weaknesses of available products and services have become essential.

"Basic problems do, in fact, exist. These problems are amenable to solution, but only when and if the powerful tools of empirical studies and human factors applications to these problems can be applied to all aspects of the man-machine relationship."

A key man-machine interface in microform systems is the film reader, the point where the user interacts with the system and obtains the information he needs from the display. It is important to know how the display

parameters interact to affect legibility. As part of the present study, two experiments were conducted to obtain quantitative information on these interactions.

Further, it is necessary to know the characteristics of available readers and microform equipment. The second portion of the study consisted of a survey of currently available microform equipment. The survey included major U.S. and foreign manufacturers. In addition to summarizing specifications on available cameras, film processors and duplicators, reader-printers, and readers, descriptions of representative storage and retrieval systems were prepared.

Although a comprehensive analysis of shipboard applications was beyond the scope of this effort, an attempt was made in the third phase of the study to categorize the types of information processing, and storage and retrieval activities characteristic of shipboard environment. This conceptualization provides an overview of the generic functions involved and helps to shed light on potential shipboard applications.

The equipment survey and generic description of shipboard information processing activities together with the empirical study of legibility formed the basis of conclusions and recommendations concerning shipboard application of microform systems.

PART I

EMPIRICAL INVESTIGATION OF DISPLAY LEGIBILITY

Conditions imposed by the shipboard environment were considered in selecting the parameters to be investigated. Aboard ship, the environment differs in several important aspects from commercial or institutional settings for which most microform equipment is designed. One factor is the almost continuous presence of vibration. Another is the range of ambient light conditions, including low light levels required for operator maintenance of dark adaptation.

Shipboard Vibration

Vibration aboard ship is described as follows in MIL-STD-167B(Ships) dated 11 August 1969, Paragraph 5.1.1.1 Steady State.

"All machinery and equipment installed aboard naval ships will ordinarily be subjected to varying frequencies and amplitudes of vibration, possibly for long periods of time during which the machinery and equipment must continue to perform their normal functions. Principal causes of steady state shipboard vibration are (a) propeller blade excitation, and (b) unbalanced forces of propeller and shafting. The vibration frequencies encountered aboard ship vary from zero to approximately 33 hertz (Hz), (2000 cycles per minute (c.p.m.)). In some of the latest surface ships, frequencies of up to 50 Hz (3000 c.p.m.) have been observed. The severity of vibration on a ship depends upon the type of ship and the location of equipment within the ship's structure."

Paragraph 5.1.1.2 Transient.

"Vibration measurements for steady state conditions are usually made in relatively quiet seas and during steady speed operations. However, ships do not operate under these conditions for any extended length of time as the speed, heading, and sea state may change. A change in any one of these conditions such as sea state has a great effect on the longitudinal, vertical, and athwartship vibration levels. The increase in displacement amplitude is almost proportional to wave height."

Table 1 below from the above MIL Standard shows shipboard vibration for steady state conditions.

TABLE 1

Vibratory Displacement of Environmental Vibration

Frequency Range (Hz)	Table Amplitude (inch)
4 to 15	0.030 ± 0.006
16 to 25	.020 ± .004
26 to 33	.010 ± .002
34 to 40	.005 ± .001
41 to 50	.003 ± .000

It may be noted that the steady state amplitudes indicated may be increased by several times in rough sea and during maneuvers. If such vibration acted upon a critical element of an optical projection system such as a prism or mirror, image displacement would be proportional to the projection distance involved. Thus, it is conceivable that shipboard vibration could be amplified sufficiently to severely degrade legibility of the projected image.

Shipboard Ambient Light

Depending upon the location and use of the microform reader, a wide range of ambient light conditions may be imposed. It may not be possible to increase or decrease ambient light levels because of requirements for other activities in the immediate vicinity. In some instances, shielding of the display may be possible while for other applications, it may be necessary for several people to view the display simultaneously, making shielding impractical.

Another consideration aboard ship is the need in certain circumstances for the potential users of microform readers to maintain their dark adaptation. Pilots in the ready room and flight deck personnel aboard a carrier are two examples. A relevant question here is whether use of red overlays, goggles, or other means may be employed while using a viewer and what effect this might have on display legibility.

Additional Factors

Along with the foregoing considerations are the basic factors of image size, brightness, polarity, and resolution. An important question is the manner in which these basic parameters interact with each other and the shipboard variables to affect display legibility. The experiments conducted in the present study were designed to provide definitive answers to these questions.

Relationship of Display Characteristics to Reading Speed and Accuracy

Experiments were conducted to determine the effect of several display parameters on legibility as measured by reading speed and accuracy. Because of the large number of variables involved, it was necessary to perform two separate experiments. In the first experiment, the effect of image brightness, size, resolution, polarity, vibration frequency and amplitude, and ambient light were examined. In the second experiment, the variable of display color (white vs. red) was introduced and variation in ambient light was eliminated. Also, the second experiment used a smaller range of image brightness. All other variables and test procedures were the same as in Experiment No. 1. Different subjects were used in each experiment.

Experiment No. 1

Method

Apparatus. A special display system was constructed to permit precise manipulation of the experimental display parameters. As illustrated in Figure 1, the system was comprised of a Kodak Carousel projector, Model 650, equipped with a projection Ektanar, F/3.5, 3-inch objective lens. The image beam was interrupted by two front surface mirrors and reflected onto the back of a Polacoat rear-projection screen. The first mirror was mounted on an electronically operated driver which caused the mirror (and display image) to oscillate at selected frequencies and amplitudes. The second mirror was stationary. A filter mount was located directly in front of the projector objective lens. Image/background color was varied by inserting a red filter* in this mount in the second experiment.

A separate control panel, connected by cable to the display unit, permitted remote control of the system.

Brightness of the display image (projector lamp brightness) was controlled by a continuously adjustable triac circuit along with appropriate neutral density filters to minimize color temperature shift at low brightness levels. A 500 watt projector lamp produced a maximum screen brightness of 130 ft-L on the viewing side.

The projection screen was recessed 32 inches within a four-sided enclosure. White incandescent lamps were recessed behind plexiglass diffusing screens in the top surface of the enclosure to control ambient light. Ambient light intensity was adjustable at the main control panel of the device. A separate continuously adjustable triac circuit was employed to control the ambient lamps. (Note: Ambient light was varied in Experiment No. 1; in Experiment No. 2, the ambient lights remained off.) The ambient lamps

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*Kodak No. 24 Red.

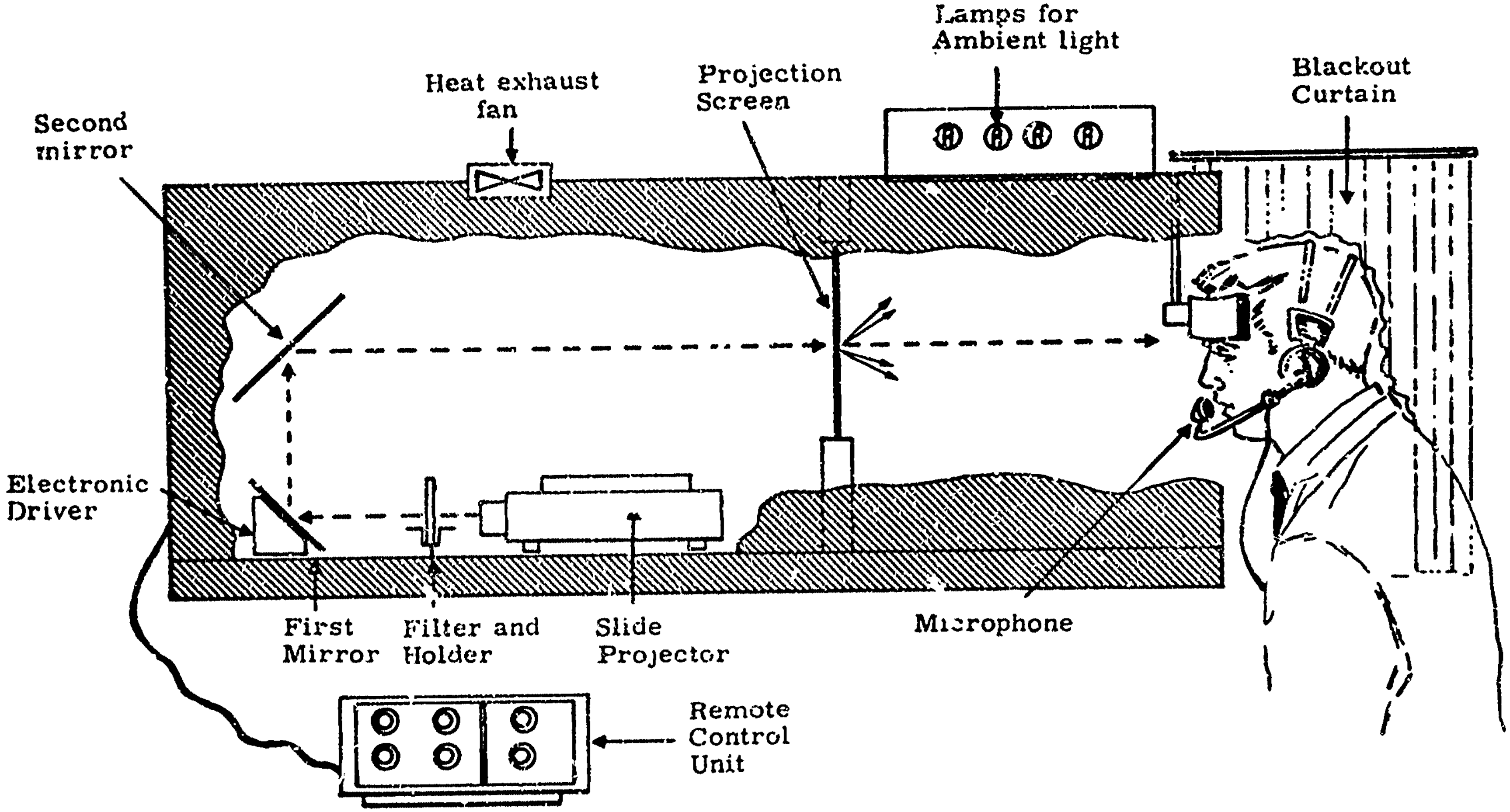


Figure 1. Cutaway view of the display system.

provided an average maximum illumination of 100 ft-c on the enclosure walls which were painted mat white. Surface reflectance was 0.80, yielding a maximum surround brightness of 80 ft-L.

A headrest was suspended from the upper enclosure surface to provide a constant viewing distance of 28 inches to the center of the screen. (This distance is normally used in human factors specifications on displays.) A blackout curtain, suspended from two arms extending from the top of the enclosure, ensured exclusion of extraneous light.

As indicated in Figure 1, the projection system controlled vibration, color, image brightness, and ambient light. The remaining variables were controlled through preparation of the stimulus transparencies.

Stimulus Transparencies. Variation in image size, resolution, and polarity was established photographically in the production of the 35 mm test transparencies. Original material was typed on good quality white bond paper using an IBM Selectric typewriter. The type was 12 point, 12 pitch, IBM Letter Gothic (Code 005). Each page contained a single paragraph of 100 words. The typed pages were photographed with a Nikon FTN Camera using a Macro-Nikor F/2 preset lens. The camera was mounted on an animatograph calibrated in .0001 inches. Ektachrome ERB film was used to achieve the desired degree of resolution and density. (Initial attempts to work with black and white film were unsuccessful because of film grain and loss of resolution in the reversal process.)

Negative slides (light letters on dark background) were produced as original negatives. To achieve the positive slides (dark letters on light background) Kodolith negatives were made using 4 mil polyester film to avoid shrinkage or expansion. These negatives were then photographed and the resulting negatives were developed yielding the desired positive transparencies. Thus, both sets of transparencies, positive and negative, were

originals, and therefore, not subjected to an intermediate reversal process. The resulting transparencies were of high resolution and high contrast.

Stimulus Content. Twenty-seven paragraphs were excerpted from a high school level textbook (Copeland, 1964). A wide range of subject matter was selected (physics, government, sociology, geography, psychology, physiology, etc.) to reduce possible effects due to content familiarity and to provide a reasonably wide vocabulary. Care was taken to exclude paragraphs with unusual words and those containing excessive repetition of words, phrases, or proper nouns. In general, the materials were considered to be factual, informative, and reasonably interesting. Two sets of the 27 paragraphs were produced as 35 mm transparencies, one set was positive, the other negative. Each set of 27 transparencies represented three levels of size and three levels of resolution with three slides within each cell of the 3 x 3 matrix.

Testing Environment. Testing was conducted in an 8' x 12' room which was quiet and had no windows. Lights were turned off during testing. A fan in the projector cooling system tended to mask any ambient noise which might on occasion have been present.

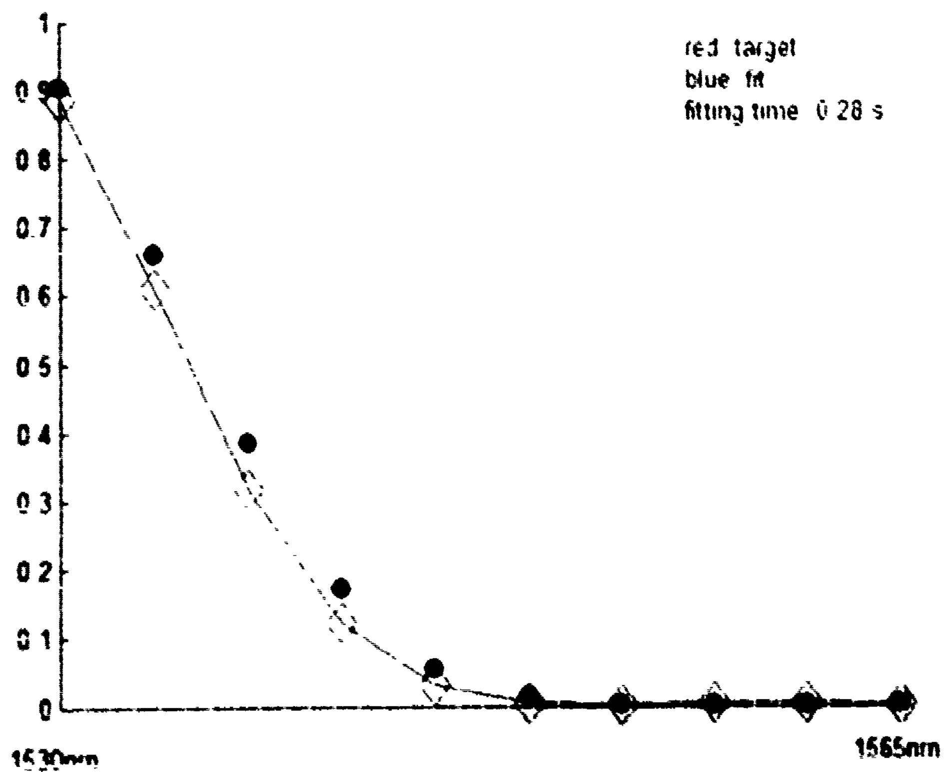
Subjects. The subjects were male and female junior college students attending Northern Virginia Community College. All were paid volunteers. Subjects ranged from 17 to 27 years in age. Each subject was screened using a Titmus Industrial Vision Tester. The test included near and far visual acuity (binocular and monocular), vertical and lateral phoria, color vision, and stereopsis (binocular depth perception). Requirements for 20/30 far visual acuity, 14/16 near visual acuity, and normal color vision were established arbitrarily and individuals who failed to reach these criteria were excluded from participation. Also, any individuals exhibiting problems of visual over- or under-convergence were excluded.

$\phi = 0.02*1$ is the initial phase offset. The combined function for the five stage filter is

$$\prod (1 - \sin(\frac{1.25\times10^{7} u}{\lambda})\cos(\frac{1.25\times10^{4} v + \phi}{\lambda}))$$

Since our initial condition is arbitrary, we made no assumptions at all about the target functions, so the fitting speed varies, depending on situations. But for most common situations, it takes less than one second to finish the fitting. For those slower cases, appropriate assumptions about the target functions can significantly speed up the fitting.

Some typical fitting examples are shown below with fitting time indicated on upper-right corners.



Forty-eight subjects were selected at random for Experiment No. 1; twenty-four for Experiment No. 2; and twenty served as control subjects reading only from typed materials. The latter subjects provided baseline data on paragraph reading times and difficulty.

Dependent Measures. Because of the nature of the task, it was necessary to use more than a single dependent measure. Two logical measures were reading rate and errors. Reading rate was defined as the number of words read correctly (i.e., words read minus misread words) divided by time taken for the total words read. For example, if a subject read 100 words in 30 seconds but misread two words, his reading rate would be (100-2)/30.

Errors were considered to be of two kinds. One was where a word was misread, e.g., "over" read as "often". Omissions or words simply not attempted was the second type of error.

The range of display legibility varied from excellent to unreadable. Where the display was clearly legible, errors would be negligible and reading rate would be an adequate measure of performance. Where display legibility was poor and only a small portion of the words could be read, errors would be an appropriate measure reflecting the difficulty of the task. For moderate legibility, however, neither measure by itself would adequately describe performance as related to task difficulty. For example, if a subject read 30 words correctly in 15 seconds, his reading rate would be 30/15 or two words per second. This, however, does not indicate that more than two thirds of the paragraph could not be read. Similarly, the omission score would be 70 percent. But this does not tell how quickly the legible words were read. Clearly, both measures are necessary to present an accurate picture of task difficulty, i.e., display legibility. Both were obtained and analyzed separately. However, to facilitate analysis and interpretation of the data, a combined score (P) was computed using both reading rate and

errors/omissions. The combined score was the product of reading rate and the proportion of the paragraph read correctly.

In treating the performance scores, two additional operations were performed. First, reading rate in words per second was converted to words per minute. Second, each score was adjusted for the reading difficulty of each paragraph apart from any experimental treatment effects.

Although an attempt was made to select paragraphs of equal reading difficulty, it was felt that small differences would still exist. To permit appropriate adjustment of the performance scores, baseline measures were obtained for each paragraph. Twenty subjects, not participating in the experiments proper, were asked to read each of the 27 test paragraphs out loud from the original typewritten copy. The mean reading rate (errors were less than 1 percent) was then calculated for each paragraph based on these 20 subjects.

The overall mean reading time (averaging across subjects and paragraphs) was 30 seconds. The mean time for each paragraph (averaging across the 20 subjects) ranged from 26 seconds to 36 seconds.

A weight was then computed for each paragraph to normalize its average reading rate with respect to the overall mean of 30 seconds.

For example, if the mean time for a given paragraph was 28 seconds, the weight (w) was calculated as 30/28 or 1.07. The score for each subject on that paragraph would then be multiplied by 1.07.

If, for example, the mean time for another paragraph was 35 seconds, its weight would be 30/35 or 0.86.

In computing the combined rate and error scores (P), errors were converted to accuracy scores so that all measures would have the same positive

relationship to performance. For example, an error/omission score of 30 percent corresponds to an accuracy score of 70 percent. All reading rate scores were adjusted according to this weighting process.

The combined score was computed as shown in Equation 1.

$$P = kw\,(RA) \qquad \text{(Equation 1.)}$$

where:

- P = combined score (reading rate corrected for display legibility (accuracy of reading) and paragraph difficulty). Units are words per minute.
- k = 60, to convert words per second to words per minute.
- w = weight correcting for paragraph reading difficulty as explained above.
- R = observed reading rate, words per second.
- A = reading accuracy (proportion of paragraph read correctly).

Procedure. The subject was seated at the apparatus. Tape recorded instructions were presented after which the experimenter provided any necessary clarification as to procedures. Subjects were told that the experiment was attempting to find out how the quality of a projected image was related to reading speed and accuracy. They were simply to read the projected paragraphs out loud as quickly, clearly, and accurately as possible without running words together. Each paragraph was numbered. The subject was to call off the number and then immediately commence reading out loud.

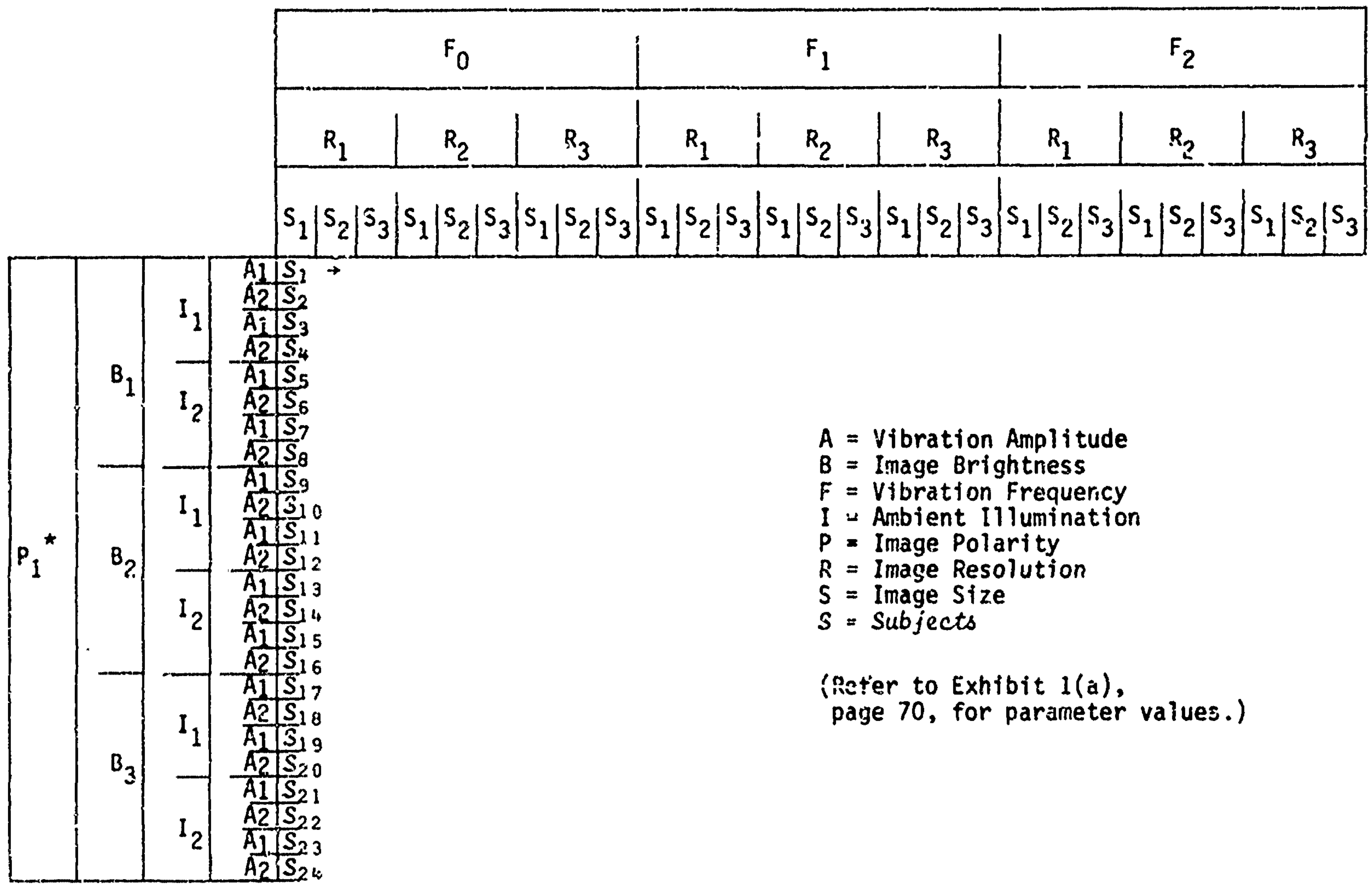
In the instructions, subjects were encouraged to continue trying to read even though they might lose the "sense" of the paragraph because of poor viewing conditions. If this happened, they were to scan a line at a time and report any words or phrases which they could still read. Upon completing the paragraph, the subject was to say "next", whereupon the experimenter presented the next slide.

A wire harness worn around the neck held a small microphone in place approximately 3 inches in front of the subject's mouth. As the subject read, his voice was recorded on an individual tape cartridge for later analysis.

Before beginning the test proper, each subject was given a typewritten paragraph and asked to read it out loud quickly but in a normal manner to check the recording level. This task served as a warm-up and practice trial. Then, the subject faced the apparatus and placed his forehead against the padded head rest. He was presented a total of 27 paragraphs in predetermined, random sequence. The only change necessary during testing was in vibration frequency. Nine of the slides were presented without vibration, nine were at 15 Hz vibration, and nine were at 30 Hz. The remaining test conditions, including vibration amplitude, were preselected before testing began and did not change during testing of a given subject.

Statistical Design

A mixed analysis of variance design, as shown in Figure 2, was selected to permit evaluation of the interactions while keeping the size of the experiment within reason. In this mixed design, subjects operating under a given combination of treatment conditions are exposed to all combinations of the remaining variables. Those treatments which are common to all subjects are termed "within-subjects" variables. Those divided among subjects are termed "between-subjects" variables. In this experiment, resolution, image size,



A = Vibration Amplitude
B = Image Brightness
F = Vibration Frequency
I = Ambient Illumination
P = Image Polarity
R = Image Resolution
S = Image Size
S = *Subjects*

(Refer to Exhibit 1(a), page 70, for parameter values.)

*(Design is replicated for P_2)

Figure 2. Mixed analysis of variance design. (Experiment No. 1)

and vibration frequency were within-subjects variables. The between-subjects variables were image brightness, polarity, ambient illumination, and vibration amplitude.

Values of the test parameters are presented in Exhibit 1(a) (page 70) which may be folded out for easy reference.

Results

An analysis of variance was done on each of the dependent measures, (1) reading rate, (2) error rate converted to percent correct, and (3) the combined score defined by Equation 1 discussed earlier.

The data for all three measures were also plotted and visually inspected. Generally, the statistically significant effects fell in the expected directions. Performance was better for displays of high resolution and brightness and large size. Performance was also better in the absence of vibration and under low ambient illumination.

Initial inspection and statistical analysis revealed that image polarity (positive vs. negative) did not differentially affect performance nor did polarity interact with any other variable. Polarity was, therefore, eliminated from further consideration in this experiment. The data were reanalyzed ignoring polarity.

Table 2 presents the analysis of variance summary on reading rate. Results of the analysis of error rate (percent correct) are shown in Table 3. It may be seen that certain statistically significant terms are common to both tables while others are not. As explained previously, each of these measures by itself does not adequately reflect task difficulty, and therefore, these findings are presented as a matter of only passing interest. The combined score gives the best indication of the manner in which overall reading performance varied in response to the different display conditions. A

TABLE 2

Analysis of Variance on Reading Rate

Source	df	MS	Error Term	F
Between Subjects	47			
Ambient Illumination (I)	3	33872.89	(1)	3.11*
Image Brightness (B)	2	137911.02	(1)	12.65**
Vibration Amplitude (A)	1	1052607.60	(1)	96.57**
B x I	6	39078.61	(1)	3.59*
A x I	3	5821.79	(1)	--
A x B	2	2111.12	(1)	--
A x B x I	6	10250.39	(1)	--
(1) Ss/A x B x I (Error Term)	24	10900.20		
Within Subjects	1248			
Vibration Frequency (F)	2	284504.51	(2)	171.32**
Image Size (S)	2	132789.51	(3)	187.07**
Image Resolution (R)	2	174455.52	(4)	327.47**
F x S	4	17862.26	(5)	34.08**
F x R	4	2028.35	(6)	2.96*
R x S	4	45511.59	(7)	144.40**
F x I	6	1035.74	(2)	--
B x F	4	3991.33	(2)	2.40
A x F	2	265919.95	(2)	160.13**
I x S	6	1662.59	(3)	2.34*
B x S	4	2842.41	(3)	4.00**
A x S	2	30352.50	(3)	42.76**
I x R	6	778.26	(4)	1.46
B x R	4	774.97	(4)	1.45
A x R	2	15439.50	(4)	28.98**

TABLE 2 (cont.)

Analysis of Variance on Reading Rate

Source	df	MS	Error Term	F
Within Subjects (cont.)				
F x I x S	12	617.73	(5)	1.18
B x F x S	8	1122.62	(5)	2.14
A x F x S	4	8225.43	(5)	15.69**
F x I x R	12	548.88	(6)	--
B x F x R	8	742.79	(6)	1.08
A x F x R	4	4361.80	(6)	6.37**
I x R x S	12	475.00	(7)	1.51
B x R x S	8	305.73	(7)	--
A x R x S	4	15646.11	(7)	49.64**
F x R x S	8	3218.22	(8)	6.11**
B x F x I	12	1064.27	(2)	--
A x F x I	6	1444.89	(2)	--
A x B x F	4	5680.59	(2)	3.42*
B x I x S	12	608.00	(3)	--
A x I x S	6	373.99	(3)	--
A x B x S	4	1184.70	(3)	1.67
B x I x R	12	721.44	(4)	1.35
A x I x R	6	309.98	(4)	--
A x B x R	4	1503.00	(4)	2.82*
B x F x I x S	24	1352.93	(5)	2.58**
A x F x I x S	12	2112.52	(5)	4.03**
A x B x F x S	8	2089.42	(5)	3.98**
B x F x I x R	24	749.07	(6)	1.09
A x F x I x R	12	773.35	(6)	1.13
A x B x F x R	8	905.39	(6)	1.32

TABLE 2 (cont.)

Analysis of Variance on Reading Rate

Source	df	MS	Error Term	F
Within Subjects (cont.)				
B x I x R x S	24	211.32	(7)	--
A x I x R x S	12	430.07	(7)	1.36
A x B x R x S	8	697.27	(7)	2.21*
F x I x R x S	24	750.27	(8)	1.42
B x F x R x S	16	332.89	(8)	--
A x F x R x S	8	4607.82	(8)	8.75**
A x B x F x I	12	1798.78	(2)	1.08
A x B x I x S	12	874.39	(3)	1.23
A x B x I x R	12	1163.47	(4)	2.18*
A x B x F x I x S	24	1251.10	(5)	2.39**
A x B x F x I x R	24	639.52	(6)	--
A x B x I x R x S	24	362.22	(7)	1.15
B x F x I x R x S	48	630.73	(8)	1.20
A x F x I x R x S	24	667.30	(8)	1.27
A x B x F x R x S	16	1094.68	(8)	2.08*
A x B x F x I x R x S	48	524.19	(8)	--
Error Terms				
(2) Ss x F/A x B x I	48	1660.61		
(3) Ss x S/A x B x I	48	709.85		
(4) Ss x R/A x B x I	48	532.74		
(5) Ss x F x S/A x B x I	96	524.19		
(6) Ss x F x R/A x B x I	96	684.35		
(7) Ss x R x S/A x B x I	96	315.17		
(8) Ss x F x R x S/A x B x I	192	526.81		

* p<.05

** p<.01

TABLE 3

Analysis of Variance on Error Rate (Percent Correct)

Source	df	MS	Error Term	F
Between Subjects	47			
Ambient Illumination (I)	3	.6194	(1)	4.34*
Image Brightness (B)	2	2.0182	(1)	14.17**
Vibration Amplitude (A)	1	27.2977	(1)	191.70**
B x I	6	.6179	(1)	4.34**
A x I	3	.2838	(1)	1.99
A x B	2	.7861	(1)	5.52*
A x B x I	6	.2010	(1)	1.41
(1) Ss/A x B x I (Error Term)	24	.1424		
Within Subjects	1248			
Vibration Frequency (F)	2	7.1544	(2)	143.37**
Image Size (S)	2	5.5344	(3)	345.90**
Image Resolution (R)	2	3.2954	(4)	177.17**
F x S	4	1.0921	(5)	82.73**
F x R	4	.4869	(6)	46.82**
R x S	4	.2945	(7)	12.37**
F x I	6	.0590	(2)	1.18
B x F	4	.3157	(2)	6.33**
A x F	2	6.4616	(2)	129.49**
I x S	6	.0248	(3)	1.55
B x S	4	.0162	(3)	1.01
A x S	2	3.6974	(3)	231.09**
I x R	6	.0093	(4)	--
B x R	4	.0909	(4)	4.89**
A x R	2	1.4601	(4)	78.50**
F x I x S	12	.0271	(5)	2.05*

TABLE 3 (cont.)

Analysis of Variance on Error Rate (Percent Correct)

Source	df	MS	Error Term	F
Within Subjects (cont.)				
B x F x S	8	.0257	(5)	1.95
A x F x S	4	.8507	(5)	64.45**
F x I x R	12	.0223	(6)	2.14*
B x F x R	8	.0148	(6)	1.42
A x F x R	4	.3127	(6)	30.07**
I x R x S	12	.0141	(7)	--
B x R x S	8	.0091	(7)	--
A x R x S	4	.2588	(7)	10.87**
F x R x S	8	0485	(8)	4.4
B x F x I	12	.0857	(2)	1.72
A x F x I	6	.0572	(2)	1.15
A x B x F	4	.1892	(2)	3.79*
B x I x S	12	.0114	(3)	--
A x I x S	6	.0335	(3)	2.09
A x B x S	4	.0857	(3)	5.36**
B x I x R	12	.0058	(4)	--
A x I x R	6	.0181	(4)	--
A x B x R	4	.0300	(4)	1.61
B x F x I x S	24	.0306	(5)	2.32**
A x F x I x S	12	.0396	(5)	3.00**
A x B x F x S	8	.0575	(5)	4.36**
B x F x I x R	24	.0251	(6)	2.41**
A x F x I x R	12	.0201	(6)	1.93*
A x B x F x R	8	.0199	(6)	1.91
B x I x R x S	24	.0172	(7)	--
A x I x R x S	12	.0120	(7)	--

TABLE 3 (cont.)

Analysis of Variance on Error Rate (Percent Correct)

Source	df	MS	Error Term	F
Within Subjects (cont.)				
A x B x R x S	8	.0448	(7)	4.07**
F x I x R x S	24	.0185	(8)	1.68*
B x F x R x S	16	.0161	(8)	1.46
A x F x R x S	8	.0605	(8)	5.50**
A x B x F x I	12	.0785	(2)	1.57
A x B x I x S	12	.0433	(3)	2.71**
A x B x I x R	12	.0371	(4)	1.99*
A x B x F x I x S	24	.0317	(5)	2.40**
A x B x F x I x R	24	.0270	(6)	2.60**
A x B x I x R x S	24	.0096	(7)	--
B x F x I x R x S	48	.0099	(8)	--
A x F x I x R x S	24	.0088	(8)	--
A x B x F x R x S	16	.0368	(8)	3.34**
A x B x F x I x R x S	48	.0122	(8)	1.12
Error Terms				
(2) Ss x F/A x B x I	48	.0499		
(3) Ss x S/A x B x I	48	.0160		
(4) Ss x R/A x B x I	48	.0186		
(5) Ss x F x S/A x B x I	96	.0132		
(6) Ss x F x R/A x B x I	96	.0104		
(7) Ss x R x S/A x B x I	96	.0238		
(8) Ss x F x R x S/A x B x I	192	.0110		

* $p<.05$

** $p<.01$

summary of the analysis of variance based on the combined score is presented in Table 4. Also, all graphs presented below are based on the combined measure.

In a study of this kind, there tends to be a considerable amount of interaction among the experimental variables. For example, letters of different size may all be equally legible (with respect to a given performance criterion) under static viewing conditions; but when vibration is introduced, they become legible to different degrees. The prevailing level of contrast or image brightness may further differentially affect legibility in conjunction with letter size and vibration. In such instances, one has less interest in the "main effects" of each individual variable, that is, in the performance means for a given variable averaged across all other conditions, than in performance observed under specific combinations of treatment variables, namely, the significant interaction effects.

On the other hand, there may be strong effects due to specific variables which tend to maintain their general form when plotted as elements of an interaction. For this reason, we will briefly examine the significant main effects before proceeding to the interactions. Values for each variable are presented in Exhibit 1(b) (page 70). The exhibit may be folded out for easy reference.

Image Size (S). Figure 3(a) shows reading performance for the three sizes of image used. It may be seen that S_2 is associated with the best performance followed closely by S_3 (largest size used) and then S_1 (smallest size used). What is not revealed here but is apparent in the size x resolution interaction is that S_2 tended to be less vulnerable to reduced resolution levels and vibration than did S_1 or S_3. Reasons for this are suggested later in the discussion of interactions involving size, resolution and vibration.

TABLE 4

Analysis of Variance on the Combined Score (P)

Source	df	MS	Error Term	F
Between Subjects	47			
Ambient Illumination (I)	3	37151.89	(1)	3.15*
Image Brightness (B)	2	146114.90	(1)	12.38**
Vibration Amplitude (A)	1	1236388.32	(1)	104.78**
B x I	6	40815.55	(1)	3.46*
A x I	3	4545.02	(1)	--
A x B	2	3378.45	(1)	--
A x B x I	6	11584.46	(1)	--
(1) Ss/A x B x I (Error Term)	24	11799.38		
Within Subjects	1248			
Vibration Frequency (F)	2	339295.72	(2)	214.35**
Image Size (S)	2	161558.92	(3)	193.29**
Image Resolution (R)	2	186405.39	(4)	356.06**
F x S	4	21797.20	(5)	13.25**
F x R	4	2114.84	(6)	2.96*
R x S	4	42051.59	(7)	102.76**
F x I	6	915.12	(2)	--
B x F	4	4123.99	(2)	2.60*
A x F	2	312172.59	(2)	197.22**
I x S	6	2114.15	(3)	2.53*
B x S	4	3657.11	(3)	4.38**
A x S	2	38738.76	(3)	46.35**
I x R	6	700.58	(4)	1.34
B x R	4	1203.63	(4)	2.30
A x R	2	13039.11	(4)	24.91**
F x I x S	12	787.39	(5)	--

TABLE 4 (cont.)

Analysis of Variance on the Combined Score (P)

Source	df	MS	Error Term	F
Within Subjects (cont.)				
B x F x S	8	1592.11	(5)	--
A x F x S	4	9702.99	(5)	5.90**
F x I x R	12	711.03	(6)	--
B x F x R	8	993.05	(6)	1.39
A x F x R	4	3588.56	(6)	5.02**
I x R x S	12	445.46	(7)	1.09
B x R x S	8	259.21	(7)	--
A x R x S	4	26218.87	(7)	64.07**
F x R x S	8	4922.36	(8)	9.06**
B x F x I	12	1276.86	(2)	--
A x F x I	6	1407.90	(2)	--
A x B x F	4	4579.51	(2)	2.89*
B x I x S	12	664.76	(3)	--
A x I x S	6	459.43	(3)	--
A x B x S	4	2053.86	(3)	2.46
B x I x R	12	731.74	(4)	1.40
A x I x R	6	364.16	(4)	--
A x B x R	4	2061.48	(4)	3.94**
B x F x I x S	24	1485.16	(5)	--
A x F x I x S	12	2043.52	(5)	1.24
A x B x F x S	8	2242.02	(5)	1.36
B x F x I x R	24	895.72	(6)	1.25
A x F x I x R	12	947.41	(6)	1.33
A x B x F x R	8	1261.77	(6)	1.77
B x I x R x S	24	230.32	(7)	--
A x I x R x S	12	600.11	(7)	1.47

TABLE 4 (cont.)

Analysis of Variance on the Combined Score (P)

Source	df	MS	Error Term	F
Within Subjects (cont.)				
A x B x R x S	8	946.60	(7)	2.31*
F x I x R x S	24	728.62	(8)	1.34
B x F x R x S	16	401.89	(8)	--
A x F x R x S	8	7026.96	(8)	12.94**
A x B x F x I	12	2304.40	(2)	1.46
A x B x I x S	12	1105.22	(3)	1.32
A x B x I x R	12	[illegible]31.35	(4)	2.73**
A x B x F x I x S	24	1338.91	(5)	--
A x B x F x I x R	24	793.88	(6)	1.11
A x B x I x R x S	24	441.28	(7)	1.08
B x F x I x R x S	48	682.04	(8)	1.26
A x F x I x R x S	24	719.00	(8)	1.32
A x B x F x R x S	16	1210.48	(8)	2.23**
A x B x F x I x R x S	48	629.85	(8)	1.16
Error Terms				
(2) Ss x F/A x B x I	48	1582.87		
(3) Ss x S/A x B x I	48	835.85		
(4) Ss x R/A x B x I	48	523.52		
(5) Ss x F x S/A x B x I	96	1644.58		
(6) Ss x F x R/A x B x I	96	714.22		
(7) Ss x R x S/A x B x I	96	409.22		
(8) Ss x F x R x S/A x B x I	192	543.20		

* $p<.05$

** $p<.01$

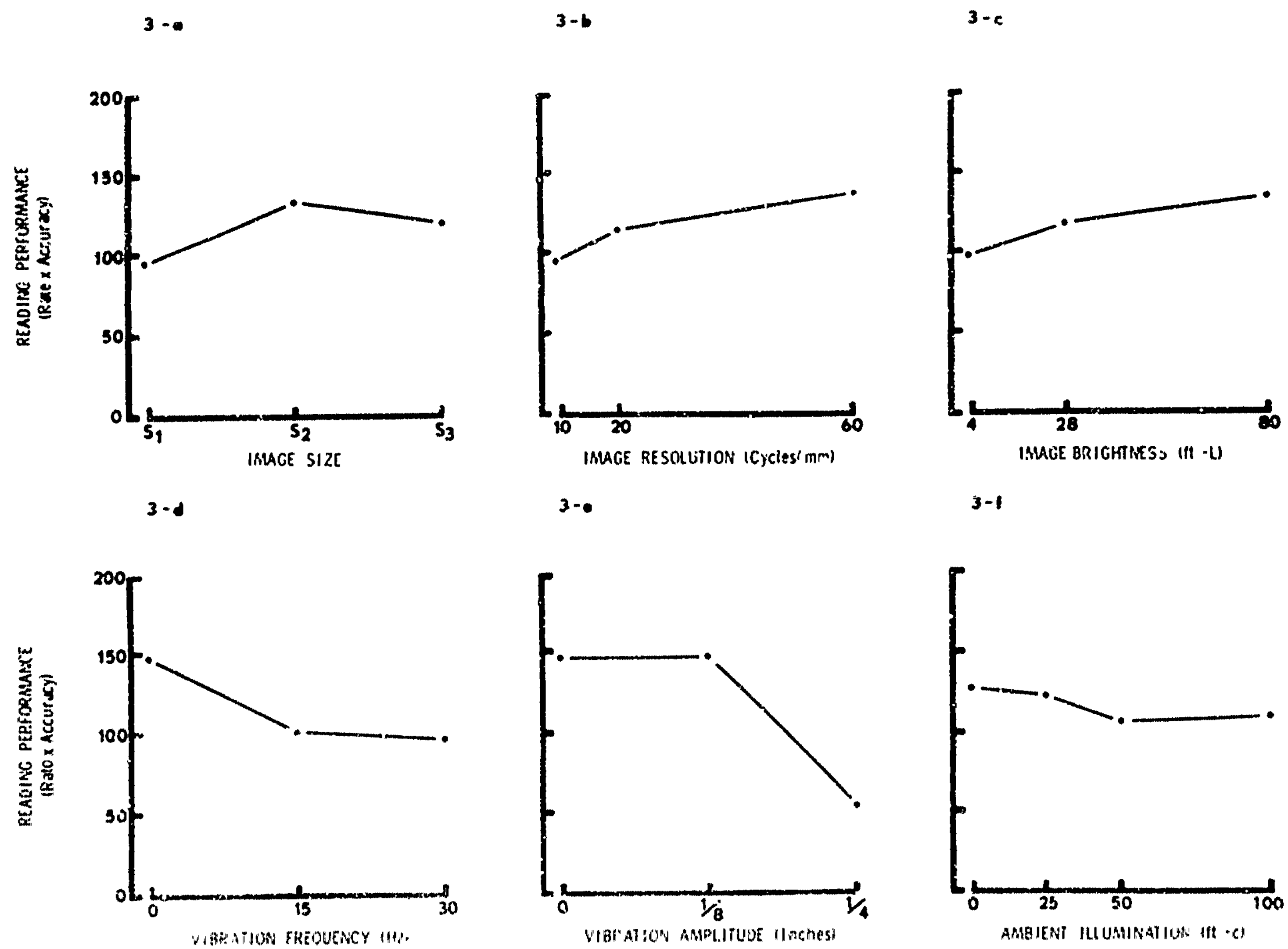


Figure 3. Reading performance as a function of display parameters: (a) image size, (b) image resolution, (c) image brightness, (d) vibration frequency, (e) vibration amplitude, (f) ambient illumination.

Image Resolution (R). Figure 3(b) shows the effect of image resolution when performance scores are averaged across all othe reatment conditions. Generally, performance improved as image resolution improved.

Image Brightness (B). Figure 3(c) presents reading performance for the three levels of image brightness used. Overall, performance improved as image brightness increased. However, there are important limitations which are shown later in the brightness x ambient illumination interaction. The "best" level of image brightness depends upon ambient viewing conditions among other things.

Vibration Frequency (F). Figure 3(d) shows the effect of vibration frequency on reading performance, averaged across vibration amplitude and the remaining test variables. Vibration produced a strong decrement in performance. The apparently small difference between 15 Hz and 30 Hz, when tested separately, was statistically significant at the .05 level.

Vibration Amplitude (A). Figure 3(e) shows performance under the two levels of vibration amplitude. While 1/8-inch vertical oscillation of the image had a very small effect, 1/4-inch amplitude had a devastating effect, particularly for the small image size (S_1). (See vibration amplitude x image size in Figure 5(c).)

Ambient Illumination (I). Figure 3(f) shows performance as a function of ambient illumination. Performance was somewhat better at low ambient illumination levels as would be expected. Again, the effect is differentiated at different levels of image brightness. (See image brightness x ambient illumination in Figure 4(c).)

Image Resolution x Image Size (R x S). Figure 4(a) shows the combined effect of image resolution and image size on reading performance. It may be seen that at the lowest resolution level (10 cycles/mm), the smallest image size used (S_1) is associated with the poorest performance. The largest size (S_3) is next, and the middle sized image (S_2) is best. At the highest resolution level (60 cycles/mm), S_3 is best, S_2 next, and S_1 poorest.

It must be noted at this point that in all subsequent graphs, where data have been averaged across levels of resolution, S_2 appears superior to S_1 and S_3. It owes this apparent superiority to the better performance associated with it at the lower levels of resolution used.

Image Brightness x Image Size (B x S). Figure 4(b) shows reading performance as a function of image brightness with image size as the parameter. As can be seen, there is improvement in performance with increased image brightness. The larger two image sizes (S_2 and S_3) improved at a slightly faster rate than S_1.

Image Brightness x Ambient Illumination (B x I). Figure 4(c) presents reading performance as a function of ambient illumination with image brightness as the parameter. Performance associated with all image brightness levels used showed a general decline as ambient illumination increased from 25 ft-c to 100 ft-c. The reversal of the B_1 (low image brightness) curve between 50 and 100 ft-c is considered as chance variability in the data.

An interesting reversal occurs between 25 ft-c and 0 ft-c [illegible] illumination. Performance associated with the dim image (B_1 = 4 ft-L) becomes best while that for the brightest image (B_3 = 80 ft-L) becomes poorest. The magnitude of the effect is small here but it can readily be ve.ified by looking at the test display. Under low ambient illumination (0 ft-c), the 80 ft-L image appears too bright--there is irradiation or spilling of light around

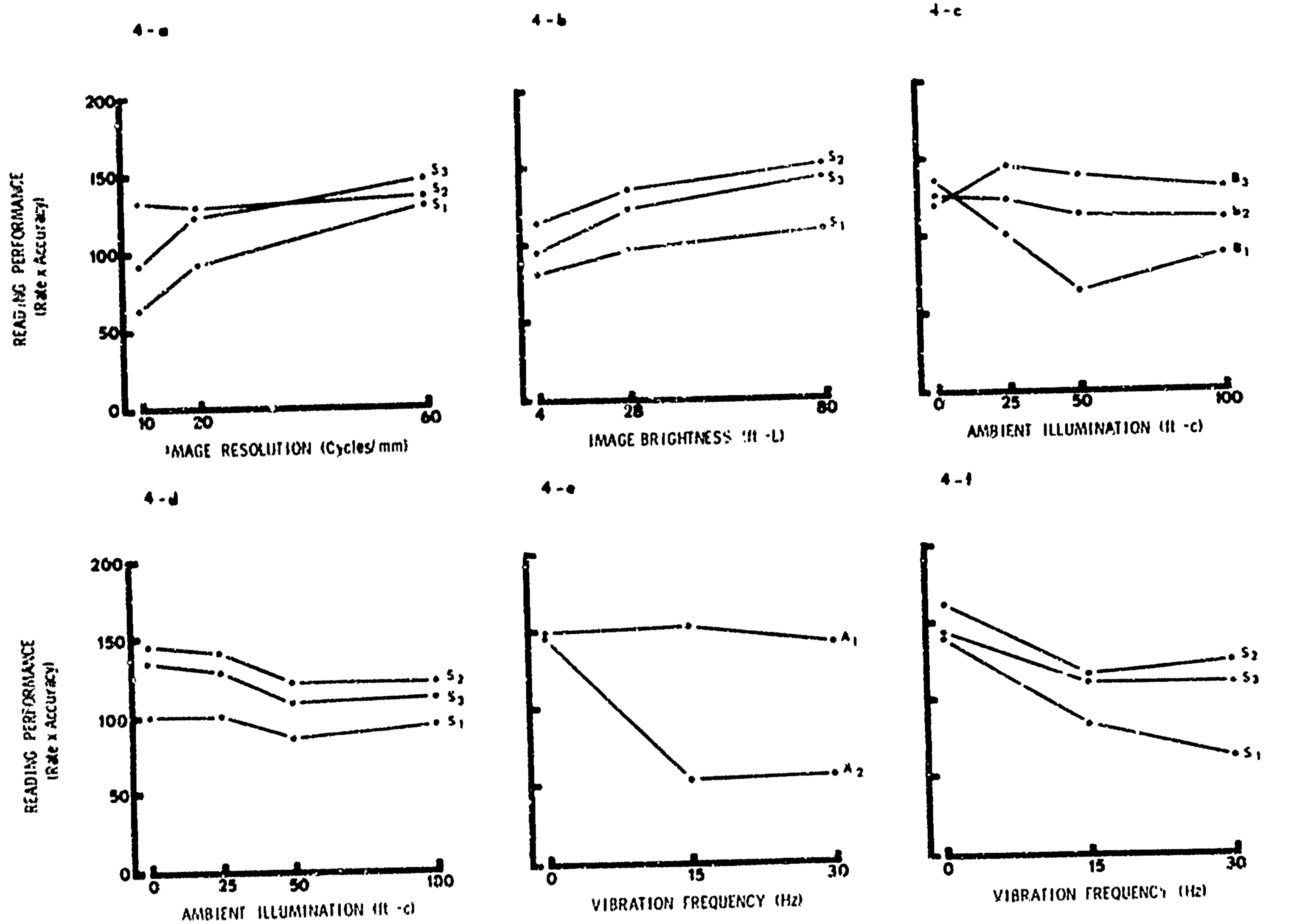


Figure 4. Reading performance as a function of two-parameter interactions: (a) image brightness x image resolution, (b) image brightness x image size, (c) image brightness x ambient illumination, (d) ambient illumination x image size, (e) vibration amplitude x vibration frequency, (f) vibration frequency x image size.

the edges of each letter. Further, when the bright image is vibrated under low ambient illumination, it prolongs persistence of the retinal image which tends to decrease legibility. An image of low brightness is definitely more legible and more comfortable to read under low ambient light.

Ambient Illumination x Image Size (I x S). Shown in Figure 4(d) are the combined effects of ambient illumination and image size. As ambient illumination increases, performance associated with the three sizes tends to decline with the largest decline occurring over the 0 to 50 ft-c range.

Performance for the small image (S_1) is consistently poorer than for the other two sizes and does not change appreciably across levels of ambient light. The curves tend to converge at the highest level of ambient illumination.

Vibration Amplitude x Vibration Frequency (A x F). Reading performance is shown in Figure 4(e) as a function of vibration frequency with vibration amplitude as the parameter. The two data points at the left (0 frequency) represent viewing conditions in which no vibration was present. Introduction of 1/8-inch amplitude oscillation did not markedly affect performance when averaged across all other conditions. The 1/4-inch amplitude vibration, however, was highly disruptive.

These data were retested omitting the 0 frequency (no-vibration) data. The A x F interaction was still statistically significant (F=8.55; d.f.=1, 24). Although the effect is small when the control data are ignored, the results suggest that the disruptive effects of vibration depend conjointly on frequency and amplitude.

Vibration Frequency x Image Size (F x S). Figure 4(f) shows clearly a differential effect of vibration frequency on reading performance for different sizes of image. Performance declines noticeably between zero-frequency (no-vibration) and 15 Hz. From 15 Hz to 30 Hz, the S_2 and S_3 curves show no further drop while the S_1 (small image size) continues to decline.

Vibration Frequency x Image Resolution (F x R). Figure 5(a) shows reading performance as a function of vibration frequency with image resolution as the parameter. The separate effects of resolution and vibration frequency are clear but the basis of their statistically significant interaction is not as apparent. Most likely, it is because there is more separation between the curves at 15 Hz and 30 Hz than at 0 Hz (no-vibration) but the difference, as demonstrated here, would not seem to be of practical consequence.

Image Brightness x Vibration Frequency (B x F). The effect of vibration frequency on reading performance for different levels of image brightness is shown in Figure 5(b). It can be seen that all three brightness curves decline between 0 and 15 Hz and tend to diverge. From 15 to 30 Hz, the higher brightness curves (B_3 and B_2) tend to level off while B_1 (lowest brightness) apparently continues to decline.

Vibration Amplitude x Image Size (A x S). The differential effect of vibration amplitude on the legibility of different sized images is shown in Figure 5(c). The A_0 curve represents the no-vibration control condition (same data as F_0 = 0 Hz). It may be seen that there was essentially no difference in performance between the no-vibration condition (A_0) and 1/8-inch amplitude vibration (A_1). However, under 1/4-inch amplitude, performance for all image sizes was reduced substantially. Performance

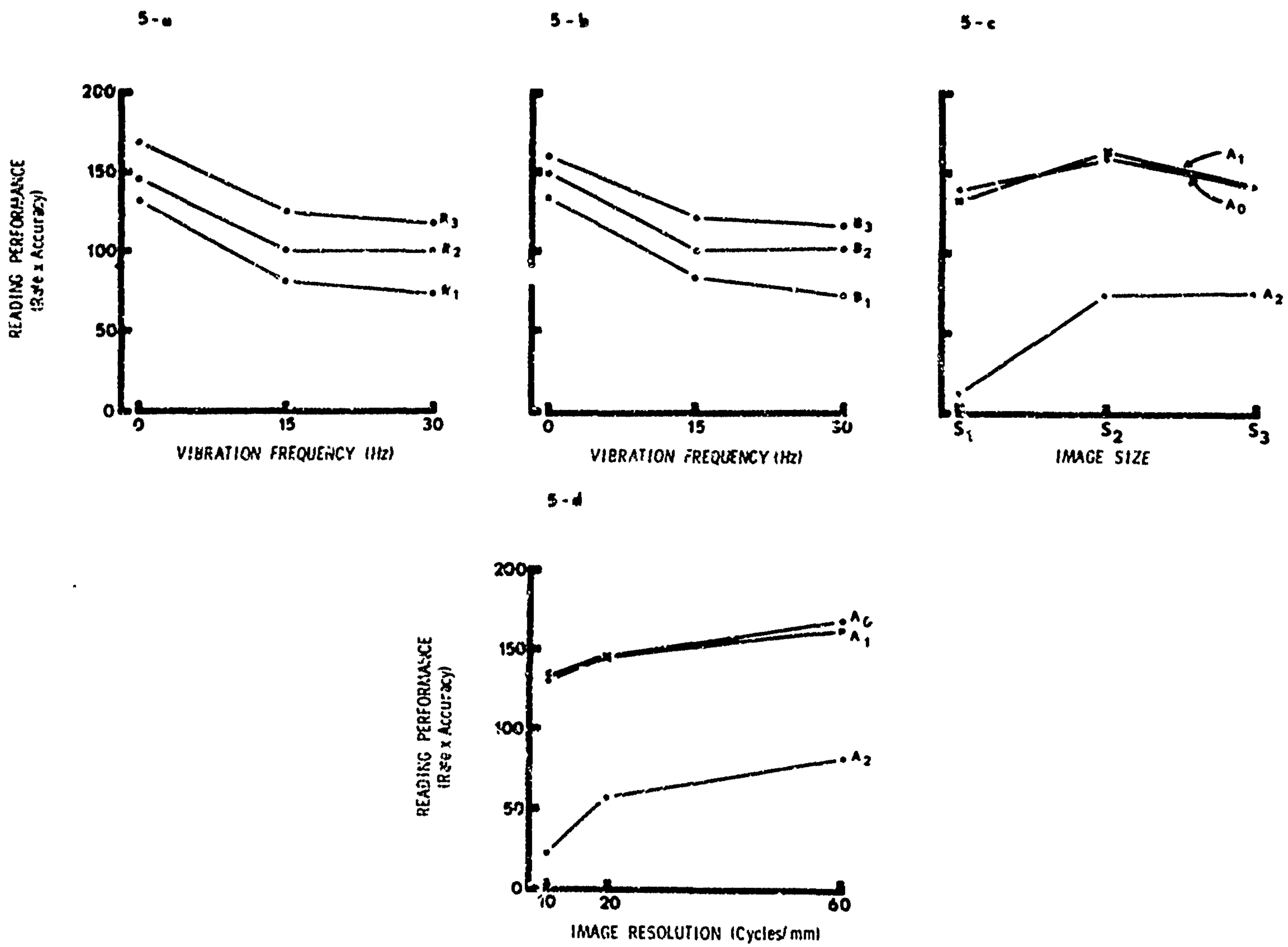


Figure 5. Reading performance as a function of two-parameter interactions: (a) vibration frequency x image resolution, (b) image brightness x vibration frequency, (c) vibration amplitude x image size, (d) vibration amplitude x image resolution.

for image sizes S_3 and S_2 was reduced by 50 percent and the S_1 images were rendered illegible (performance scores reduced by 90 percent relative to the no-vibration condition).

Vibration Amplitude x Image Resolution (A x R). Figure 5(d) shows reading performance as a function of image resolution for the different conditions of vibration amplitude. As in the A x S interaction above, there is essentially no difference between the A_0 (no-vibration) and A_1 (1/8-inch amplitude) curves. Introduction of 1/4-inch amplitude oscillation reduced performance at high and medium resolution levels by more than 50 percent while at low resolution the display was rendered virtually illegible.

Vibration Amplitude x Image Resolution x Image Size (A x R x S). The interaction of vibration amplitude, image resolution, and image size is shown in Figures 6(a), 6(b), and 6(c). Each figure represents a different level of image resolution. Looking at Figure 6(a) which represents the lowest resolution level used, it may be seen that under 1/4-inch vibration amplitude the smallest image (S_1) reflects the poorest performance, with S_3 (largest size) next, and S_2 best. The same relationship among image sizes holds for the zero and 1/8-inch vibration conditions with little difference between the latter two curves. Moving to Figure 6(b), the next higher resolution level used, the A_0 and A_1 curves still fall close together but there is now less difference across the three sizes of image. Under the 1/4-inch vibration (A_2), it can be seen that S_2 and S_3 have been helped somewhat by the increased resolution but S_1 is still essentially illegible.

Finally at R_3, Figure 6(c), it can be seen that A_0 (no-vibration) and A_1 (1/8-inch vibration) are clearly separated with A_0 representing consistently better performance. Also, there is the suggestion that at the high level of resolution and low vibration amplitude, the smaller image (S_1) is associated with better reading performance. When 1/4-inch vibration (A_2) is

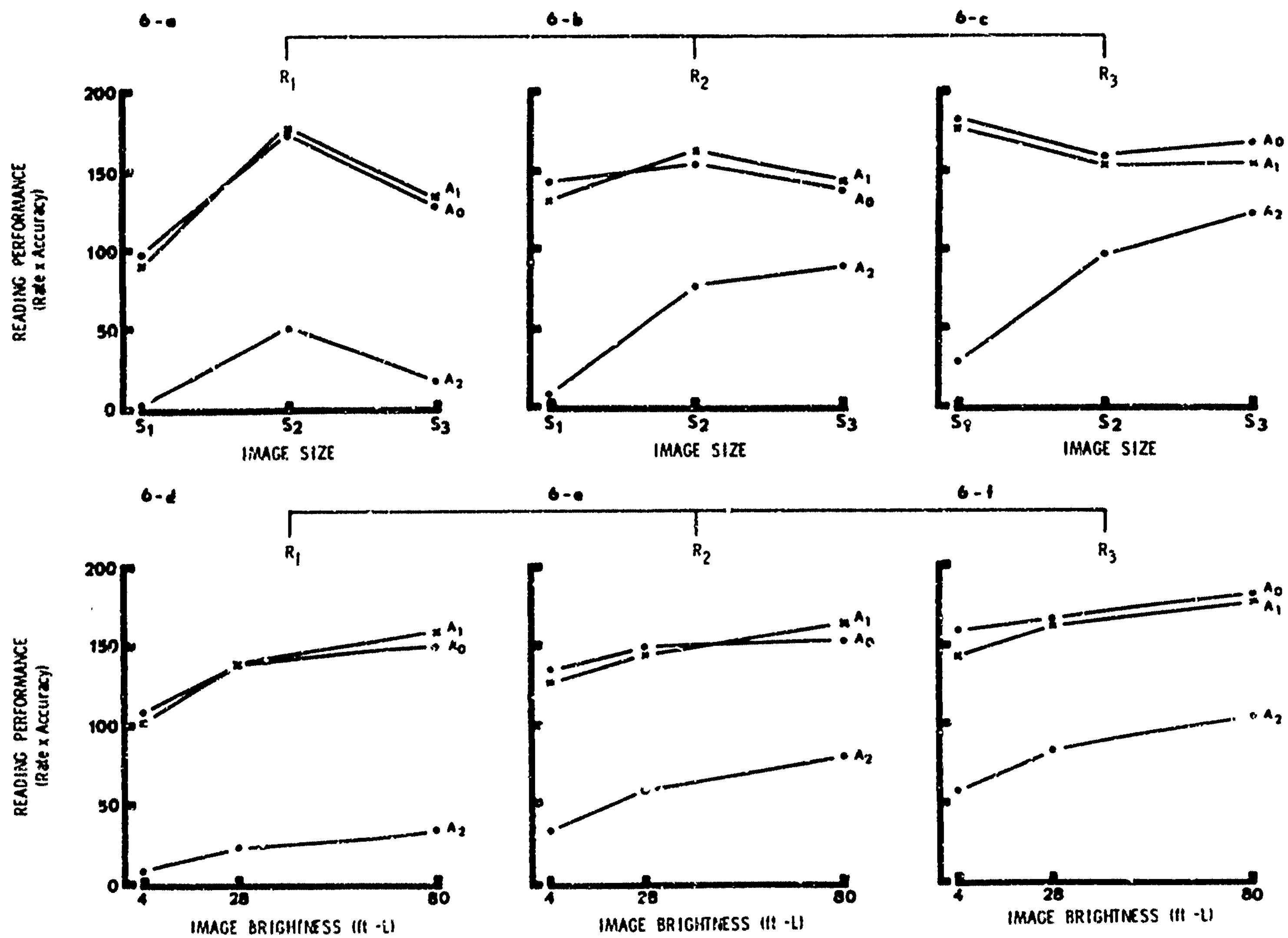


Figure 6. Reading performance as a function of three-parameter interactions:
(a, b, c) image brightness x vibration frequency x image size,
(d, e, f) vibration amplitude x image brightness x image resolution.

introduced, the degradation which results is inversely related to image size and again S_1 becomes illegible for all practical purposes.

<u>Vibration Amplitude x Image Brightness x Image Resolution (A x B x R)</u>. Figures 6(d), 6(e), and 6(f) show this interaction. Viewing the three figures from left to right (increasing resolution), it can be seen that overall there is a general improvement in reading performance, somewhat more so for the A_2 (1/4-inch vibration) condition.

At R_3 (Figure 6(f)), the A_0 and A_1 curves are clearly separated showing a small but consistent decrement due to 1/8-inch vibration (A_1). Performance under the 1/4-inch vibration condition (A_2) still falls well below the other two. This difference is most pronounced for the lowest image brightness (4 ft-L).

<u>Vibration Amplitude x Image Brightness x Vibration Frequency (A x B x F)</u>. This interaction is shown in Figure 7(a). No A_0 curve is shown since the zero frequency condition represents the no-vibration control condition. (A_0 data and F_0 data are the same scores.)

It may be seen that the six curves fall into two separate groups across 15 and 30 Hz. This grouping is due to the difference in vibration amplitude (A_1 = 1/8-inch vs. A_2 = 1/4-inch). Within each group, the curves are ordered clearly with respect to image brightness, higher brightness being associated with better performance.

In the A_1 group, the curves tend to diverge with a greater rate of degradation suggested for the low image brightness curve (A_1, B_1). In the A_2 group, there is only the smallest suggestion of a decline for B_3 and B_1 across 15 and 30 Hz. B_2 exhibits an apparent reversal, however, these scores (less than 100) represent generally poor performance due to poor display legibility and data variability is greater in this performance range.

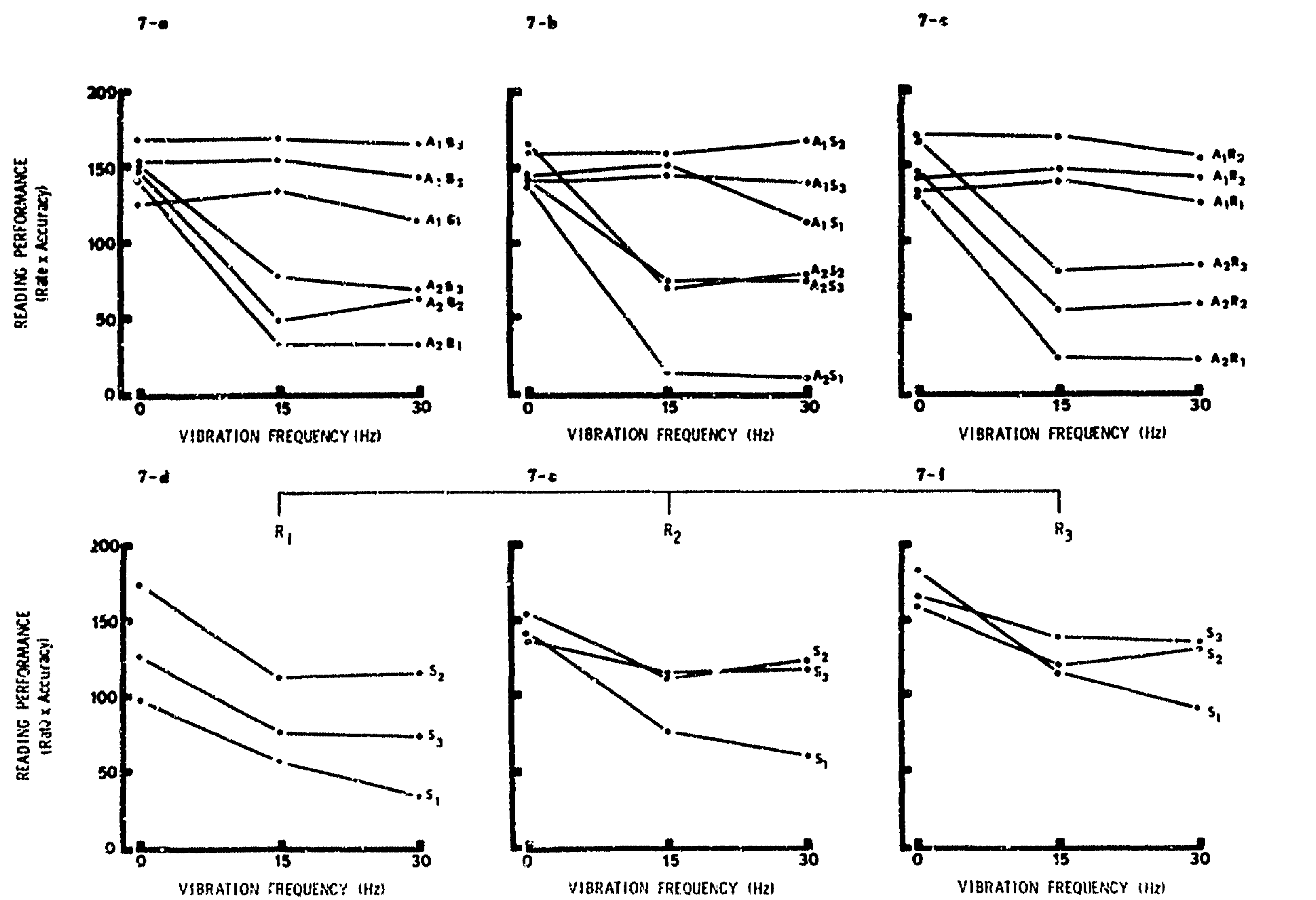


Figure 7. Reading performance as a function of three-parameter interactions: (a) vibration amplitude x image brightness x vibration frequency, (b) vibration amplitude x vibration frequency x image size, (c) vibration amplitude x vibration frequency x image resolution, (d, e, f) vibration frequency x image resolution x image size.

Looking carefully at the zero frequency (no-vibration) condition at the left, it may be seen that the data points are ordered generally in direct relation to image brightness.

Vibration Amplitude x Vibration Frequency x Image Size (A x F x S). This interaction is presented in Figure 7(b). The differential effects of amplitude and image size have been shown in Figure 5(c). Here it is of interest to see whether the A x S effect differs for different levels of vibration frequency. Two points are worth noting. One is the degradation of performance for the A_1S_1 curve in going from 15 Hz to 30 Hz, suggesting that small images are more sensitive to vibration frequency than larger ones.

Second is the form of the A_2S_1 curve. The effect of frequency here is only slight but at 15 Hz, the A_2S_1 curve has little room for further decline.

Vibration Amplitude x Vibration Frequency x Image Resolution (A x F x R). As seen in Figure 7(c), the A_2 (1/4-inch amplitude) curves tend to diverge as vibration frequency increases from 0 to 15 to 30 Hz. The A_2R_1 curve, representing the lowest resolution used, shows a slight decline from 15 to 30 Hz. Overall, it appears that the differential effects of frequency, while statistically significant, are not pronounced in influencing the A x R effect.

Vibration Frequency x Image Resolution x Image Size (F x R x S). This interaction is shown in Figures 7(d), 7(e), and 7(f). In 7(d), representing the lowest resolution level, the curves for image size are clearly separated. While S_2 and S_3 show an initial drop in going from zero frequency (no-vibration) to 15 Hz, they appear to level off with no further decline at 30 Hz. However, S_1 continues to decline indicating the vulnerability of a small, low resolution image to vibration frequency.

As resolution increased, Figures 7(e) and 7(f), performance generally increased. At R_2, the difference between S_2 and S_3 is greatly reduced but S_1 still lags behind. At R_3 (Figure 7(f)), S_1 is associated with the best performance of the three sizes at zero vibration but declines as vibration frequency increases. At 30 Hz, S_1 is again poorest. Even at high resolution, the smallest image is vulnerable to vibration frequency.

The remaining statistically significant higher order interactions were plotted and inspected visually. However, the effects involved did not seem of practical consequence, and therefore, are not presented.

Experiment No. 2

The primary purpose of this experiment was to assess the effect of red vs. white images (background for positive transparencies) on display legibility.

Method

All the apparatus, procedures, test conditions, and dependent measures were as described in Experiment No. 1 with the following exceptions.

(1) Ambient illumination was not varied; it remained at zero throughout the experiment.

(2) The factor of image/surround color was introduced. On one half of the trials, a red filter* was used to produce red letters on a dark surround for negative transparencies and dark letters against a red surround for positive transparencies.

(3) Image brightness levels were 8, 28, and 48 ft-L.

(4) Twenty-four subjects not used in Experiment No 1 participated in this experiment.

All remaining variables were as in Experiment No. 1. Values for the parameters are presented in Exhibit 1(a) (page 70) which can be folded out for easy reference.

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*Kodak No. 24 Red.

Statistical Design

A mixed analysis of variance design was used as described in Experiment No. 1. The design matrix is shown in Figure 8.

Results

In general, the results were in good agreement with those of Experiment No. 1, where corresponding conditions were tested. As in the first experiment, image polarity showed no effect either in graphic or statistical analysis of the data, and therefore, was excluded from further consideration.

The comparison of red vs. white displays also failed to reach significance and visual inspection of the data showed no effect due to use of the red filter.

Image brightness, tested over the range of 8 to 48 ft-L, was also non-significant. It will be remembered that ambient light was not varied here and the range of image brightness tested was apparently not great enough to have a pronounced effect.

Certain other variables were not significant here although they were found to be so in Experiment No. 1. This might be expected in that less subjects were used in the second experiment, and therefore, small but real effects would be less likely to be detected.

Results of the analyses of variance are presented in Tables 5, 6, and 7, corresponding respectively to the three dependent measures: (1) reading rate, (2) accuracy, and (3) the combined score (P) as defined earlier in Equation 1.

					F_0									F_1									F_2								
					R_1			R_2			R_3			R_1			R_2			R_3			R_1			R_2			R_3		
					S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
P_1*	B_1	C_1	A_1	S_1 →																											
			A_2	S_2																											
		C_2	A_1	S_3																											
			A_2	S_4																											
	B_2	C_1	A_1	S_5																											
			A_2	S_6																											
		C_2	A_1	S_7																											
			A_2	S_8																											
	B_3	C_1	A_1	S_9																											
			A_2	S_{10}																											
		C_2	A_1	S_{11}																											
			A_2	S_{12}																											

A = Vibration Amplitude
B = Image Brightness
C = Image Color
F = Vibration Frequency
P = Image Polarity
R = Image Resolution
S = Image Size
S = *Subjects*

(Refer to Exhibit 1(a), page 70, for parameter values.)

*(Design is replicated for P_2)

Figure 8. Mixed analysis of variance design. (Experiment No. 2)

TABLE 5

Analysis of Variance on Reading Rate

Source	df	MS	Error Term	F
Between Subjects	23			
Image Color (C)	1	1932.35	(1)	--
Image Brightness (B)	2	7676.22	(1)	2.24
Vibration Amplitude (A)	1	519010.68	(1)	151.25**
B x C	2	12438.35	(1)	3.62
A x C	1	15070.41	(1)	4.39
A x B	2	6414.30	(1)	1.87
A x B x C	2	13176.86	(1)	3.84
(1) Ss/A x B x C (Error Term)	12	3431.37		
Within Subjects	624			
Vibration Frequency (F)	2	178852.10	(2)	112.20**
Image Size (S)	2	77893.50	(3)	90.72**
Image Resolution (R)	2	80867.14	(4)	98.74**
F x S	4	2785.05	(5)	1.47
F x R	4	3218.98	(6)	3.51*
R x S	4	29073.88	(7)	110.25**
C x F	2	5066.48	(2)	3.18
B x F	4	2738.81	(2)	1.72
A x F	2	189154.18	(2)	118.66**
C x S	2	308.51	(3)	--
B x S	4	3415.29	(3)	3.98*
A x S	2	4805.48	(3)	5.60*
C x R	2	1105.64	(4)	1.35
B x R	4	487.69	(4)	--
A x R	2	5413.50	(4)	6.61**
C x F x S	4	379.87	(5)	--

TABLE 5 (cont.)

Analysis of Variance on Reading Rate

Source	df	MS	Error Term	F
Within Subjects (cont.)				
B x F x S	8	1610.49	(5)	--
A x F x S	4	1908.27	(5)	1.01
C x F x R	4	676.52	(6)	--
B x F x R	8	1117.01	(6)	1.22
A x F x R	4	1008.05	(6)	1.10
C x R x S	4	545.55	(7)	2.07
B x R x S	8	217.26	(7)	--
A x R x S	4	6467.15	(7)	24.52**
F x R x S	8	3178.02	(8)	4.21**
B x C x F	4	540.81	(2)	--
A x C x F	2	1822.07	(2)	1.14
A x B x F	4	3163.94	(2)	1.98
B x C x S	4	778.54	(3)	--
A x C x S	2	1319.40	(3)	1.54
A x B x S	4	797.39	(3)	--
B x C x R	4	487.16	(4)	--
A x C x R	2	451.27	(4)	--
A x B x R	4	2403.57	(4)	2.93*
B x C x F x S	8	2058.00	(5)	1.09
A x C x F x S	4	615.64	(5)	--
A x B x F x S	8	2640.80	(5)	1.40
B x C x F x R	8	893.79	(6)	--
A x C x F x R	4	521.88	(6)	--
A x B x F x R	8	449.21	(6)	--
B x C x R x S	8	271.36	(7)	1.03

TABLE 5 (cont.)

Analysis of Variance on Reading Rate

Source	df	MS	Error Term	F
Within Subjects (cont.)				
A x C x R x S	4	236.29	(7)	--
A x B x R x S	8	497.23	(7)	1.88
C x F x R x S	8	426.45	(8)	--
B x F x R x S	16	586.33	(8)	--
A x F x R x S	8	3919.72	(8)	5.19**
A x B x C x F	4	686.82	(2)	--
A x B x C x S	4	3006.23	(3)	3.50*
A x B x C x R	4	40[illegible]3	(4)	--
A x B x C x F x S	8	1856.[illegible]2	(5)	--
A x B x C x F x R	8	1355.12	(6)	1.48
A x B x C x R x S	8	452.30	(7)	1.72
B x C x F x R x S	16	978.70	(8)	1.30
A x C x F x R x S	8	682.92	(8)	--
A x B x F x R x S	16	321.27	(8)	--
A x B x C x F x R x S	16	767.83	(8)	1.02
Error Terms				
(2) Ss x F/A x B x C	24	1594.07		
(3) Ss x S/A x B x C	24	858.61		
(4) Ss x R/A x B x C	24	819.01		
(5) Ss x F x S/A x B x C	48	1892.42		
(6) Ss x F x R/A x B x C	48	917.87		
(7) Ss x R x S/A x B x C	48	263.70		
(8) Ss x F x R x S/A x B x C	96	755.16		

* $p<.05$

**$p<.01$

TABLE 6

Analysis of Variance on Error Rate (Percent Correct)

Source	df	MS	Error Term	F
Between Subjects	23			
Image Color (C)	1	.3147	(1)	1.88
Image Brightness (B)	2	.0045	(1)	--
Vibration Amplitude (A)	1	16.2450	(1)	97.16**
B x C	2	.0296	(1)	--
A x C	1	.2178	(1)	1.30
A x B	2	.0001	(1)	--
A x B x C	2	.0759	(1)	--
(1) Ss/A x B x C (Error Term)	12	.1672		
Within Subjects	624			
Vibration Frequency (F)	2	4.4050	(2)	58.34**
Image Size (S)	2	2.7154	(3)	151.70**
Image Resolution (R)	2	1.6594	(4)	207.42**
F x S	4	.5902	(5)	37.59**
F x R	4	.4121	(6)	57.24**
R x S	4	.1071	(7)	7.54**
C x F	2	.0776	(2)	1.03
B x F	4	.0176	(2)	--
A x F	2	4.3189	(2)	57.20**
C x S	2	.0222	(3)	1.24
B x S	4	.0433	(3)	2.42
A x S	2	1.8712	(3)	104.54**
C x R	2	.0061	(4)	--
B x R	4	.0038	(4)	--
A x R	2	1.1347	(4)	141.84**
C x F x S	4	.0112	(5)	--

TABLE 6 (cont.)

Analysis of Variance on Error Rate (Percent Correct)

Source	df	MS	Error Term	F
Within Subjects (cont.)				
B x F x S	8	.0274	(5)	1.74
A x F x S	4	.4951	(5)	31.54**
C x F x R	4	.0083	(6)	1.15
B x F x R	8	.0024	(6)	--
A x F x R	4	.2873	(6)	39.90**
C x R x S	4	.0416	(7)	2.93*
B x R x S	8	.0040	(7)	--
A x R x S	4	.2050	(7)	14.44**
F x R x S	8	.0371	(8)	4.70**
B x C x F	4	.0134	(2)	--
A x C x F	2	.0911	(2)	1.21
A x B x F	4	.0043	(2)	--
B x C x S	4	.0259	(3)	1.45
A x C x S	2	.0144	(3)	--
A x B x S	4	.0175	(3)	--
B x C x R	4	.0114	(4)	1.42
A x C x R	2	.0058	(4)	--
A x B x R	4	.0027	(4)	--
B x C x F x S	8	.0082	(5)	--
A x C x F x S	4	.0062	(5)	--
A x B x F x S	8	.0234	(5)	1.49
B x C x F x R	8	.0093	(6)	1.29
A x C x F x R	4	.0025	(6)	--
A x B x F x R	8	.0043	(6)	--
B x C x R x S	8	.0118	(7)	--
A x C x R x S	4	.0673	(7)	4.74**

TABLE 6 (cont.)

Analysis of Variance on Error Rate (Percent Correct)

Source	df	MS	Error Term	F
Within Subjects (cont.)				
A x B x R x S	8	.0148	(7)	1.04
C x F x R x S	8	.0137	(8)	1.73
B x F x R x S	16	.0037	(8)	--
A x F x R x S	8	.0670	(8)	8.48**
A x B x C x F	4	.0325	(2)	--
A x B x C x S	4	.0174	(3)	--
A x B x C x R	4	.0087	(4)	1.09
A x B x C x F x S	8	.0080	(5)	--
A x B x C x F x R	8	.0190	(6)	2.64*
A x B x C x R x S	8	.0067	(7)	--
B x C x F x R x S	16	.0126	(8)	1.59
A x C x F x R x S	8	.0176	(8)	2.23
A x B x F x R x S	16	.0055	(8)	--
A x B x C x F x R x S	16	.0057	(8)	--
Error Terms				
(2) Ss x F/A x B x C	24	.0755		
(3) Ss x S/A x B x C	24	.0179		
(4) Ss x R/A x B x C	24	.0080		
(5) Ss x F x S/A x B x C	48	.0157		
(6) Ss x F x R/A x B x C	48	.0072		
(7) Ss x R x S/A x B x C	48	.0142		
(8) Ss x F x R x S/A x B x C	96	.0079		

* $p<.05$

**$p<.01$

TABLE 7

Analysis of Variance on the Combined Score (P)

Source	df	MS	Error Term	F
Between Subjects	23			
Image Color (C)	1	19.26	(1)	--
Image Brightness (B)	2	10876.37	(1)	--
Vibration Amplitude (A)	1	622773.26	(1)	32.98**
B x C	2	15690.81	(1)	--
A x C	1	6941.37	(1)	--
A x B	2	6652.78	(1)	--
A x B x C	2	15643.14	(1)	--
(1) Ss/A x B x C (Error Term)	12	18883.94		
Within Subjects	624			
Vibration Frequency (F)	2	230513.03	(2)	146.73**
Image Size (S)	2	84444.56	(3)	80.73**
Image Resolution (R)	2	113261.20	(4)	46.50**
F x S	4	3588.32	(5)	1.78
F x R	4	4768.56	(6)	6.27**
R x S	4	19563.21	(7)	36.35**
C x F	2	5653.79	(2)	3.60*
B x F	4	1953.10	(2)	1.24
A x F	2	240229.93	(2)	152.92**
C x S	2	732.66	(3)	--
B .	4	1297.84	(3)	1.24
A x S	2	9983.79	(3)	9.54**
C x R	2	3048.89	(4)	1.25
B x R	4	3663.76	(4)	1.50
A x R	2	1682.17	(4)	--
C x F x S	4	222.44	(5)	--

TABLE 7 (cont.)

Analysis of Variance on the Combined Score (P)

Source	df	MS	Error Term	F
Within Subjects (cont.)				
B x F x S	8	2091.61	(5)	1.04
A x F x S	4	3285.01	(5)	1.63
C x F x R	4	628.34	(6)	--
B x F x R	8	960.38	(6)	1.26
A x F x R	4	1119.21	(6)	1.47
C x R x S	4	106.23	(7)	--
B x R x S	8	522.03	(7)	--
A x R x S	4	10028.67	(7)	18.63**
F x R x S	8	5103.86	(7)	8.49**
B x C x F	4	867.80	(2)	--
A x C x F	2	2133.02	(2)	1.36
A x B x F	4	1834.16	(2)	1.17
B x C x S	4	378.82	(3)	--
A x C x S	2	993.19	(3)	--
A x B x S	4	399.55	(3)	--
B x C x R	4	2933.25	(4)	1.20
A x C x R	2	3405.24	(4)	1.40
A x B x R	4	6816.16	(4)	2.80*
B x C x F x S	8	2148.42	(5)	1.06
A x C x F x S	4	691.11	(5)	--
A x B x F x S	8	2862.77	(5)	1.42
B x C x F x R	8	926.04	(6)	1.22
A x C x F x R	4	421.96	(6)	--
A x B x F x R	8	313.35	(6)	--
B x C x R x S	8	271.63	(7)	--
A x C x R x S	4	599.52	(7)	1.11

TABLE 7 (cont.)

Analysis of Variance on the Combined Score (P)

Source	df	MS	Error Term	F
Within Subjects (cont.)				
A x B x R x S	8	450.76	(7)	--
C x F x R x S	8	322.68	(8)	--
B x F x R x S	16	458.14	(8)	--
A x F x R x S	8	6096.88	(8)	10.14**
A x B x C x F	4	649.68	(2)	--
A x B x C x S	4	1950.55	(3)	1.86
A x B x C x R	4	2442.86	(4)	1.00
A x B x C x F x S	8	1705.57	(5)	--
A x B x C x F x R	8	943.50	(6)	1.24
A x B x C x R x S	8	771.85	(7)	1.43
B x C x F x R x S	16	922.95	(8)	1.53
A x C x F x R x S	8	712.75	(8)	1.18
A x B x F x R x S	16	455.38	(8)	--
A x B x C x F x R x S	16	473.32	(8)	--
Error Terms				
(2) Ss x F/A x B x C	24	1570.95		
(3) Ss x S/A x B x C	24	1046.07		
(4) Ss x R/A x B x C	24	2435.56		
(5) Ss x F x S/A x B x C	48	2017.20		
(6) Ss x F x R/A x B x C	48	760.24		
(7) Ss x R x S/A x B x C	48	538.18		
(8) Ss x F x R x S/A x B x C	96	601.38		

* $p<.05$

**$p<.01$

Since the combined score gives the more complete picture of the relationship between performance and display conditions for reasons given earlier, those results are presented below.

Image Size (S). Figure 9(a) shows reading performance as a function of image size. S_1, the smallest of the three sizes used, was associated with poorer performance than S_2 or S_3.

Image Resolution (R). As seen in Figure 9(b), performance tended to improve with increased resolution. The rate of improvement is somewhat greater from 10 to 20 cycles/mm than from 20 to 60 cycles/mm.

Vibration Frequency (F). Reading performance is shown as a function of vibration frequency in Figure 9(c). The overall significant F-ratio was due to the difference between no-vibration (0 Hz) and vibration (15, 30 Hz). The two vibration frequencies, 15 Hz vs. 30 Hz, were tested omitting the no-vibration data and found not to be significantly different.

Vibration Amplitude (A). The effect of vibration amplitude on reading performance is shown in Figure 9(d). It can be seen that 1/8-inch amplitude produced only a slight drop in performance while 1/4-inch resulted in a dramatic 67 percent loss.

Image Resolution x Image Size (R x S). Figure 9(e) shows reading performance as a function of image resolution with image size as the parameter. These curves are in very close agreement with those of Experiment No. 1 (Figure 4(a)) which used completely different subjects. At the highest resolution level used (60 cycles/mm), performance is directly related to image size with the

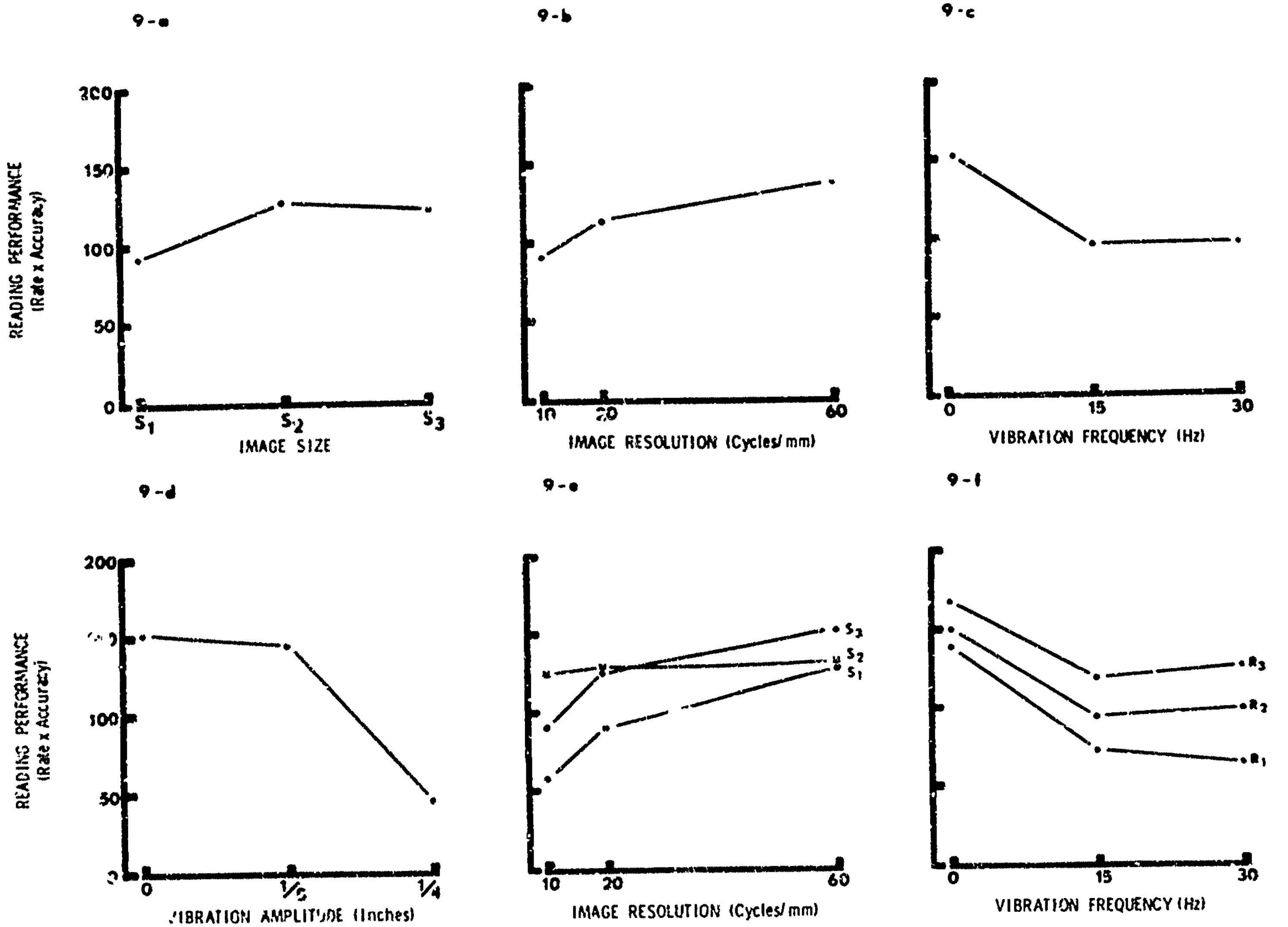

Figure 9. Reading performance as a function of display parameters: (a) image size, (b) image resolution, (c) vibration frequency, (d) vibration amplitude, (e) image resolution with image size as the parameter, (f) vibration frequency with image size as the parameter.

largest image best and the smallest image size poorest. At the lowest resolution used, S_2 is best followed by S_3, then S_1. S_1 is poorest across all resolution levels used.

Vibration Frequency x Image Resolution (F x R). As shown in Figure 9(f), reading performance was better for higher levels of resolution. The resolution curves tend to diverge, however, as vibration frequency is increased. While R_3 and R_2 show an initial drop between 0 and 15 Hz, they exhibit no further loss at 30 Hz. A small loss occurs for the lower resolution (R_1) in going from 15 to 30 Hz.

Image Color x Vibration Frequency (C x F). Figure 10(a) shows reading performance as a function of vibration frequency with image color as the parameter. Image color by itself was not statistically significant (mean performance for white = 114.5; mean performance for red = 114.1), nor was the simple effect of 15 Hz vs. 30 Hz.

It is felt that the interaction of these two factors, while statistically significant, is not of sufficient magnitude to be of practical importance.

Vibration Amplitude x Vibration Frequency (A x F). The effect of vibration amplitude and vibration frequency on performance is shown in Figure 10(b). Only the effect of amplitude is apparent. The interaction is deemed of no practical consequence.

Vibration Amplitude x Image Size (A x S). As can be seen in Figure 10(c), 1/4-inch amplitude (A_2) had a more pronounced effect on the smaller image size (S_1), rendering it illegible, while S_2 and S_3 performance levels were reduced by about 60 percent.

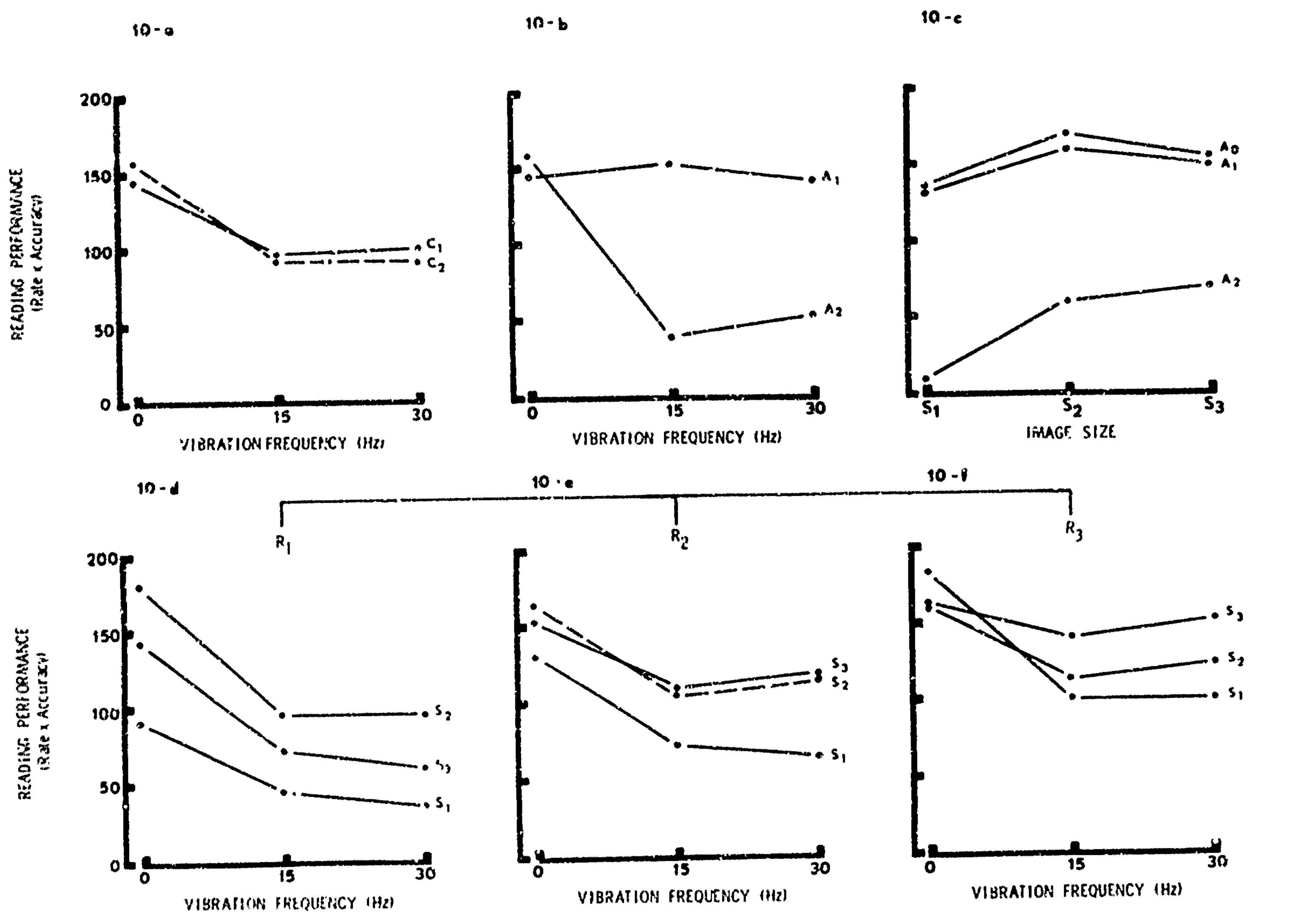

Figure 10. Reading performance as a function of parameter interactions: (a) image color x vibration frequency, (b) vibration amplitude x vibration frequency, (c) vibration amplitude x image size, (d, e, f) vibration frequency x image resolution x image size.

Vibration Frequency x Image Resolution x Image Size (F x R x S). This interaction is shown in Figures 10(d), 10(e), and 10(f), corresponding to low, medium, and high resolution levels, respectively. At low resolution (Figure 10(d)), performance curves for the respective image sizes are clearly separated with S_2 best, S_3 next, and S_1 poorest. This holds across all vibration frequencies for the low resolution (R_1) conditions. There also is a decline in performance as vibration frequency increases, most of the loss coming in the change from no-vibration to 15 Hz.

As resolution is increased, there is a general increase in performance levels. The difference between S_2 and S_3 is negligible at R_2. The smallest size image (S_1) retains its relatively inferior position at the higher resolution levels.

Under conditions of vibration at the highest resolution level (R_3), S_3 (large) is best followed by S_2 and then S_1. At 0 Hz, S_1 is best.

Vibration Amplitude x Image Resolution x Image Size (A x R x S). This interaction is shown in Figures 11(a), 11(b), and 11(c), corresponding respectively to the three levels of image resolution tested. Looking across the three figures from left to right, it can be seen that there was an overall improvement in reading performance as resolution was increased but the rate and amount of improvement depended upon the image size and the attendent vibration amplitude.

For all practical purposes, S_1 (small size) remains illegible under 1/4-inch vibration at all levels of resolution. S_2 shows some improvement, and S_3 (large size) shows marked improvement with increased resolution.

At low resolution (R_1), performance associated with the no-vibration (A_0) condition is best and is consistently about 10 percent higher than the 1/8-inch vibration condition (A_1). At low resolution, S_2 appears to be more legible than S_1 or S_3.

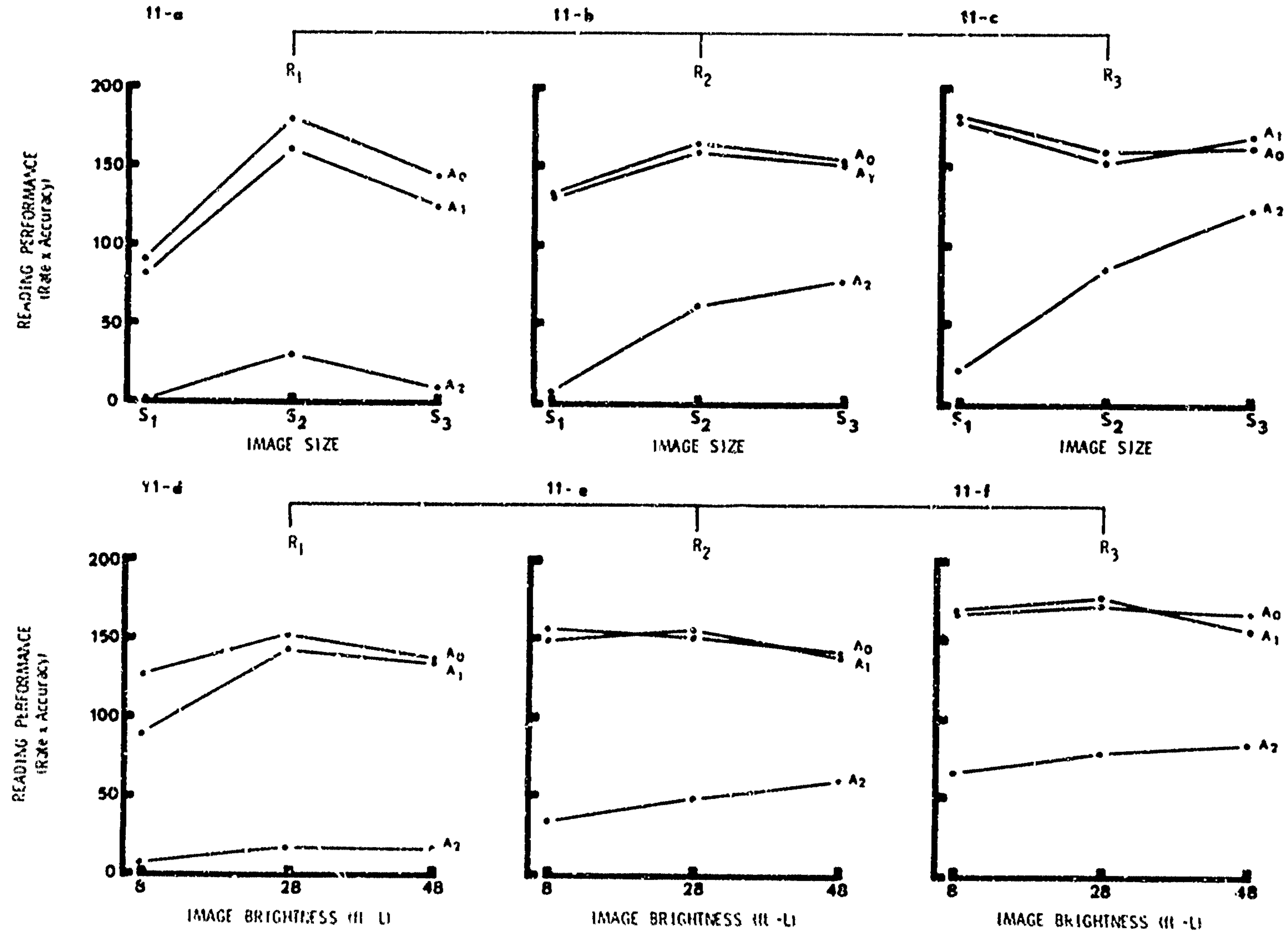

Figure 11. Reading performance as a function of parameter interactions:
(a, b, c) vibration amplitude x image resolution x image size,
(d, e, f) vibration amplitude x image brightness x image resolution.

As resolution is increased, the discrepancy between the A_0 and A_1 curves tends to disappear as does the differential effect of image size. It can be concluded that high resolution targets are less vulnerable to degradation by vibration and, conversely, the lower the resolution and smaller the image size, the greater the decrement for a given amount of vibration.

Vibration Amplitude x Image Brightness x Image Resolution (A x B x R). Figures 11(d), 11(e), and 11(f) show the A x B x R interaction. From left to right, the figures represent increasing levels of resolution. Most noticeable is the increase in performance levels depicted by the A_2 curve (1/4-inch vibration) as resolution is increased.

At R_2 and R_3, there is essentially no difference between the A_0 and A_1 curves while at low resolution (R_1), the no-vibration condition (A_0) is associated with consistently better performance than A_1 (1/8-inch vibration). In all cases, the A_2 (1/4-inch vibration) curve is associated with relatively poor reading performance although there is a consistent improvement with increased resolution.

The effect of image brightness is not pronounced. What effect there is, is most apparent in the A_0 and A_1 curves of Figure 11(d) between 8 and 28 ft-L.

DISCUSSION

The foregoing test results show the manner in which the various display parameters affected display legibility, i.e., reading speed and accuracy. It was found that for the range of conditions tested, image polarity and image color (red vs. white) had no significant effect on reading performance while image resolution, brightness, and size proved to be important determinants of legibility. Vibration of the projected image reduced legibility in proportion to the oscillation amplitude, and to a lesser degree, in relation to vibration frequency.

The individual variables affected legibility in an expected manner. More importantly, the form and magnitude of their interactions has now been determined in quantitative form. Although the curves presented show the effect of the combined parameters on legibility, the data may be presented in somewhat different form to facilitate assessment of the relative effects of each parameter. In particular, it appeared useful to express the scores relative to that performance obtained by reading hand-held, typewritten copy under good lighting conditions. It will be recalled that the necessary reference data was obtained in determining the difficulty weight for each paragraph. Twenty subjects who did not participate in the experiments proper read each of the 27 paragraphs out loud from typed copy. The overall average reading rate (errors were negligible) was 200 words per minute. The test scores were normalized with respect to 200 words per minute, e.g., a performance score of 200 was converted to 1.00, a score of 125 became 0.62, etc. The normalized scores are presented in Tables 3 through 11. In Table 8, the data have been averaged across image size while Tables 9, 10, and 11, respectively, represent the three different image sizes. Data in each table are classified according to the test conditions of ambient light, image brightness, resolution, and vibration amplitude.

The normalized scores in the tables may be viewed as legibility factors relative to reading hand held copy at a nominal distance of 14 inches. From these tables, it is possible to obtain a clearer picture of the relative

TABLE 8

Normalized Performance Scores Relative to Reading Typed Copy (200 words per minute) Averaged Across Three Image Sizes

		Ambient Illumination (I) (ft-c)											
		$I_1 = 0$			$I_2=25$			$I_3=50$			$I_4=100$		
Vibration Amplitude (A)	Image Brightness (B) (ft-L)	Image Resolution (R) (cycles/mm)											
		$R_1=10$	$R_2=20$	$R_3=60$	$R_1=10$	$R_2=20$	$R_3=60$	$R_1=10$	$R_2=20$	$R_3=60$	$R_1=10$	$R_2=20$	$R_3=60$
A_0 = 0"	B_1 = 4	.82	.86	.93	.64	.70	.82	.26	.50	.70	.46	.62	.73
	B_2 = 28	.70	.74	.86	.69	.78	.86	.71	.72	.76	.67	.72	.80
	B_3 = 80	.66	.69	.80	.79	.81	.95	.81	.74	.96	.74	.78	.91
A_1 =1/8"	B_1 = 4	.75	.83	.95	.59	.67	.71	.31	.48	.58	.39	.53	.65
	B_2 = 28	.68	.72	.85	.75	.73	.81	.66	.66	.74	.67	.76	.86
	B_3 = 80	.70	.78	.82	.93	.93	1.00	.90	.88	.94	.64	.70	.75
A_2 =1/4"	B_1 = 4	.08	.32	.57	.02	.14	.26	.00	.00	.02	.05	.14	.30
	B_2 = 28	.16	.39	.54	.12	.34	.46	.14	.32	.43	.05	.14	.27
	B_3 - 80	.17	.34	.43	.18	.43	.52	.16	.34	.47	.19	.49	.66

TABLE 9

Normalized Performance Scores Relative to Reading Typed Copy

(200 words per minute) for 0.67X Projection of 12 Point, 12 Pitch Type

Vibration Amplitude (A)	Image Brightness (B) (ft-L)	Ambient Illumination (I) (ft-c) $I_1 = 0$ $R_1=10$	$I_1=0$ $R_2=20$	$I_1=0$ $R_3=60$	$I_2=25$ $R_1=10$	$I_2=25$ $R_2=20$	$I_2=25$ $R_3=60$	$I_3=50$ $R_1=10$	$I_3=50$ $R_2=20$	$I_3=50$ $R_3=60$	$I_4=100$ $R_1=10$	$I_4=100$ $R_2=20$	$I_4=100$ $R_3=60$
		Image Resolution (R) (cycles/mm)											
$A_0 = 0"$	$B_1 = 4$	.62	.82	1.00	.48	.74	.94	.08	.34	.78	.31	.66	.73
	$B_2 = 28$	.47	.73	.91	.50	.88	.88	.54	.66	.79	.50	.72	.85
	$B_3 = 80$	.48	.68	.91	.55	.76	.97	.68	.64	1.00	.60	.90	1.00
$A_1 = 1/8"$	$B_1 = 4$	.52	.82	1.00	.38	.56	.74	.10	.41	.57	.26	.52	.70
	$B_2 = 28$	.42	.58	.96	.58	.64	.90	.49	.62	.80	.49	.74	1.00
	$B_3 = 80$	.32	.64	.80	.72	.91	1.00	.72	.78	1.00	.42	.61	.76
$A_2 = 1/4"$	$B_1 = 4$	.00	.03	.13	.00	.00	.02	.00	.00	.00	.00	.01	.16
	$B_2 = 28$	.01	.06	.22	.00	.02	.09	.00	.01	.13	.00	.02	.06
	$B_3 = 80$	.00	.06	.14	.01	.07	.12	.00	.07	.20	.00	.09	.43

TABLE 10

Normalized Performance Scores Relative to Reading Typed Copy
(200 words per minute) for 1.00X Projection of 12 Point, 12 Pitch Type

Vibration Amplitude (A)	Image Brightness (B) (ft-L)	Ambient Illumination (I) (ft-c) $I_1 = 0$			$I_2=25$			$I_3=50$			$I_4=100$		
		Image Resolution (R) (cycles/mm)											
		$R_1=10$	$R_2=20$	$R_3=60$	$R_1=10$	$R_2=20$	$R_3=60$	$R_1=10$	$R_2=20$	$R_3=60$	$R_1=10$	$R_2=20$	$R_3=60$
A_0 = 0"	B_1 = 4	1.00	.95	.92	.86	.67	.75	.58	.66	.61	.68	.68	.72
	B_2 = 28	.90	.80	.81	.90	.79	.86	.90	.80	.74	.86	.73	.76
	B_3 = 80	.80	.70	.68	.98	.96	.96	.98	.80	.84	.92	.72	.80
A_1 = 1/8"	B_1 = 4	.98	.88	.86	.82	.79	.68	.66	.58	.65	.63	.54	.63
	B_2 = 28	.92	.81	.77	.91	.82	.74	.86	.72	.70	.85	.76	.72
	B_3 = 80	.93	.97	.85	1.00	.97	.94	1.00	.99	.90	.77	.80	.78
A_2 = 1/4"	B_1 = 4	.18	.41	.75	.07	.24	.32	.00	.00	.04	.12	.25	.30
	B_2 = 28	.36	.55	.64	.31	.44	.58	.32	.42	.50	.13	.19	.38
	B_3 = 80	.37	.44	.48	.40	.58	.59	.30	.39	.50	.45	.63	.72

TABLE 11

Normalized Performance Scores Relative to Reading Typed Copy
(200 words per minute) for 1.33X Projection of 12 Point, 12 Pitch Type

		Ambient Illumination (I) (ft-c)											
		$I_1 = 0$			$I_2 = 25$			$I_3 = 50$			$I_4 = 100$		
Vibration Amplitude (A)	Image Brightness (B) (ft-L)	Image Resolution (R) (cycles/mm)											
		$R_1 = 10$	$R_2 = 20$	$R_3 = 60$	$R_1 = 10$	$R_2 = 20$	$R_3 = 60$	$R_1 = 10$	$R_2 = 20$	$R_3 = 60$	$R_1 = 10$	$R_2 = 20$	$R_3 = 60$
$A_0 = 0''$	$B_1 = 4$	.80	.82	.86	.58	.70	.79	.11	.50	.70	.38	.54	.74
	$B_2 = 28$	.72	.71	.86	.66	.66	.86	.70	.68	.74	.66	.72	.80
	$B_3 = 80$	.70	.68	.81	.84	.70	.92	.76	.80	.96	.69	.72	.89
$A_1 = 1/8''$	$B_1 = 4$	.76	.78	.86	.56	.66	.70	.18	.46	.50	.28	.54	.61
	$B_2 = 28$	.70	.78	.82	.76	.73	.80	.64	.64	.72	.68	.76	.79
	$B_3 = 80$	.84	.74	.80	.92	.91	.99	.94	.88	.88	.72	.68	.70
$A_2 = 1/4''$	$B_1 = 4$	.05	.52	.83	.01	.17	.43	.00	.00	.02	.02	.30	.44
	$B_2 = 28$	.12	.57	.74	.07	.55	.69	.10	.52	.65	.02	.20	.37
	$B_3 = 80$	.13	.51	.68	.12	.64	.87	.17	.58	.72	.12	.74	.83

effect of the different parameters and what efficiency (or loss, with respect to reading typed copy) can be expected for a given set of parametric conditions.

It can be seen, for example, that performance improved as resolution, image size, and brightness increased. There are some inversions, however. For example, under low ambient illumination, too bright an image (80 ft-L) results in a performance decrement as explained earlier. A similar inversion occurs in Table 8 under 100 ft-c ambient illumination and 1/8-inch vibration amplitude. It would appear that the normalized data provide a helpful basis for determining equivalent legibility conditions and give insight into the tradeoffs which may be made in designing or selecting displays.

In this regard, it may be seen that certain parameters are more important than others in affecting legibility. Overall, image resolution appeared to be the most important parameter. Displays with high resolution tended to resist degradation from vibration, reduced image brightness, reduced size, and high ambient illumination. When the display was of low resolution, variation in image size and brightness could not compensate for loss of legibility.

Next to resolution, image brightness appeared to be the next most important parameter. The effect of image brightness depends in part on ambient light conditions. Where ambient illumination cannot be controlled, it is important that the display have a good range of brightness levels (e.g., 5 - 80 ft-L), and that adjustment controls be available. Depending upon ambient illumination, a display can be too bright as well as too dim.

The legibility of imaged text material also depends on letter size. There are, however, obvious practical constraints in this regard, namely, the size of original copy, photographic reduction ratio, and projector magnification range. The present experiments used 12 point, 12 pitch IBM Letter Gothic

(Code 005) type (the same as was used in preparing this report). It was projected at 0.67:1, 1:1, and 1.33:1 and all sizes were viewed at 28 inches. Where resolution was good (120 lines/mm) and image brightness was high (80 ft-L), performance did not vary noticeably with letter size. However, the 0.67:1 size was much more vulnerable to degradation through vibration, reduction in brightness, and decreased resolution than the other two sizes.

At low resolution, the medium sized image (corresponding to actual typewritten size and viewed at 28 inches) gave the best results. It is possible that factors other than sharpness or contrast of image were contributing to this result. One possible factor is the relationship of line length to scan rate. A large-sized type, and hence a large overall projected image, may be more "legible" word by word but less words may be perceived at a glance. This, in turn, might result in a loss of continuity and contextual meaning which otherwise would contribute to reading speed. It is possible that both image clarity and perceptual factors, such as scanning patterns, contribute to ease of reading different sized type as measured by reading rate and accuracy.

Frequency, amplitude, and their interactions significantly affected reading performance but the effect of frequency was small in comparison to amplitude. Vibration of the image at 1/8-inch amplitude produced a small but measurable decrement in performance while 1/4-inch vibration reduced performance levels by 50 to 95 percent of those associated with steady viewing conditions. Displays having low brightness and low resolution were much more susceptible to degradation from vibration than bright, high resolution displays. As would be expected, the small image was more vulnerable to vibration than the larger sizes used.

The results show clearly that for the combinations of image brightness and ambient illumination used, it is possible to have too bright an image as well as one which is too dim (see Figure 4(c)). Under low ambient illumination, excessive brightness causes irradiation or spilling of light at the figure/ground boundaries with resulting loss of image clarity and definition.

Further, if the image is subject to vibration, excess image brightness combines with the vibration through the mechanism of retinal image persistence (the perception of an image on the retina after the stimulus is removed) to reduce visibility. The spot "seen" after watching a photo flashbulb being fired is one example. This effect can be readily verified by simply reducing the brightness of the vibrating image and observing the immediate improvement in legibility. This can be done any number of ways, e.g., by reducing projection lamp output or simply viewing the screen through a filter.

An additional word is perhaps merited concerning the parameters of image polarity and color which were found to be non-significant in the present experiments. Regarding polarity, it would appear that displays of equivalent brightness and contrast are equally legible. This is not to say that users will not express a preference for one polarity or the other. In a study of polarity preference for reading patent drawings, Bloch, et al (1968) concluded that the subjects preferred searching dark lines on a light surround. Notable in that study, however, was the observation by subjects that: "Diffusing of light was more apparent with negative film, sometimes causing images to expand and look blurred." That investigator concluded that "the blurred images resulted from light diffusion and were an inherent property of negative film, not an effect of the machine used". A similar effect was observed in the present study. However, it is felt that the problem is one of too much brightness contrast rather than an inherent characteristic of negative film. This difference in conclusions seems to support further the need for brightness controls on viewing devices. Finally, it should be noted that the present experiments did not address the issue of polarity preference. There may have been a preference even though performance was the same for positive and negative images.

Regarding the question of red vs. white images which has relevance to maintenance of operator dark adaptation, the results showed no difference in performance as a function of color. Comparisons were made under equal brightness conditions, however, and use of a red filter, goggles, etc.,

in the operational setting would possibly require a compensatory increase in display brightness. Introduction of a red filter without brightness compensation would be expected to reduce legibility depending upon the original level of brightness and other display parameters.

CONCLUSIONS

1. Display legibility is a complex entity dependent upon a range of optical, physical, and perceptual factors. The present study provides quantitative data showing the manner in which critical parameters interact and their relative contribution to or degradation of display legibility.

2. Image resolution is the single most important factor in display legibility. Under static viewing conditions and adequate image brightness and size, 20 lines/mm may represent an acceptable level of resolution. Under conditions of image vibration, 120 line/mm appears necessary to achieve any reasonable degree of display legibility.

3. Image brightness is an important element of display legibility. The means for adjusting brightness over a significant range (5 - 80 ft-L) is highly desirable and is essential where ambient light can not be controlled.

4. Ambient light is of concern to the extent that it can not be controlled. The greater the range of ambient light encountered, the greater is the need for adequate shielding of the display and provisions for display brightness adjustment.

5. Image polarity did not differentially affect display legibility as measured by reading speed and accuracy. Operator preference was not examined and conclusions in this regard may not be drawn.

6. Image vibration, depending upon the frequency and amplitude, can substantially degrade display legibility. For frequencies up to 30 Hz at least, amplitude rather than frequency appears to be the critical factor.

While 1/8-inch amplitude vibration may be tolerated under otherwise good viewing conditions, 1/4-inch vibration of the image renders the display

illegible for all practical purposes. Further, because of possible amplification by optical lever effects, (as where a mirror or prism in the projector is subjected to low amplitude vibration), image displacement of up to 1/4-inch is entirely possible in the shipboard environment.

7. Image color (white vs. red) did not differentially affect reading performance. Provided that brightness loss can be compensated for, it would appear that a red filter, goggles, etc., may be used in the operational setting without penalty to display legibility.

8. The display parameters investigated interact in a complex manner, and optimal values for one can not be independent of the others. The normalized data presented in Tables 8 through 11 provide a first estimate of tradeoffs which may be made among the parameters to achieve equivalent levels of legibility for rear projection of text materials.

Exhibit 1(b)

Values of the Test Parameters

Experiment No. 1

A -- Vibration Amplitude (inches)	$A_0=0$;	$A_1=1/8$;	$A_2=1/4$.	
B -- Image Brightness (ft-L)	$B_1=4$;	$B_2=28$;	$B_3=80$.	
F -- Vibration Frequency (Hz)	$F_0=0$;	$F_1=15$;	$F_2=30$.	
I -- Ambient Illumination (ft-c)	$I_1=0$;	$I_2=25$;	$I_3=50$;	$I_4=100$.
P -- Image Polarity	$P_1=$ negative;		$P_2=$ positive.	
R -- Image Resolution (cycles/mm)	$R_1=10$;	$R_2=20$;	$R_3=60$.	
S -- Image Size (12 pt., 12 pitch type)	$S_1=0.67:1$;	$S_2=1:1$;	$S_3=1.33:1$.	

Experiment No. 2

A -- Vibration Amplitude (inches)	$A_0=0$;	$A_1=1/8$;	$A_2=1/4$.
B -- Image Brightness (ft-L)	$B_1=8$;	$B_2=28$;	$B_3=48$.
C -- Image Color	$C_1=$ white;		$C_2=$ red.
F -- Vibration Frequency (Hz)	$F_0=0$;	$F_1=15$;	$F_2=30$.
P -- Image Polarity	$P_1=$ negative;		$P_2=$ positive.
R -- Image Resolution (cycles/mm)	$R_1=10$	$R_2=20$;	$R_3=60$.
S -- Image Size (12 pt., 12 pitch type)	$S_1=0.67:1$;	$S_2=1:1$;	$S_3=1.33:1$.

Exhibit 1(a)

Values of the Test Parameters

Experiment No. 1

A -- Vibration Amplitude (inches)
A_0= 0; A_1=1/8; A_2=1/4.

B -- Image Brightness (ft-L)
B_1= 4; B_2=28; B_3=80.

F -- Vibration Frequency (Hz)
F_0= 0; F_1 15; F_2=30.

I -- Ambient Illumination (ft-c)
I_1= 0; I_2=25; I_3=50; I_4=100.

P -- Image Polarity
P_1= negative; P_2= positive.

R -- Image Resolution (cycles/mm)
R_1=10; R_2=20; R_3=60.

S -- Image Size (12 pt. 12 pitch type)
S_1=0.67:1; S_2=1:1; S_3=1.33:1.

Experiment No. 2

A -- Vibration Amplitude (inches)
A_0= 0; A_1=1/8; A_2=1/4.

B -- Image Brightness (ft-L)
B_1= 8; B_2=28; B_3=48.

C -- Image Color
C_1= white; C_2= red.

F -- Vibration Frequency (Hz)
F_0= 0; F_1=15; F_2=30.

P -- Image Polarity
P_1= negative; P_2= positive.

R -- Image Resolution (cycles/mm)
R_1=10; R_2=20; R_3=60.

S -- Image Size (12 pt. 12 pitch type)
S_1=0.67:1; S_2= 1:1; S_3=1.33:1.

(Fold out for Exhibit 1(b).)

PART II

SURVEY OF AVAILABLE MICROFORM EQUIPMENT

The object of this phase of the study was to assemble in convenient form a reference source of presently available microform equipment. The information was obtained through correspondence with major manufacturers of the equipment in the United States and foreign countries. The technical and trade literature was searched for relevant information and leads to suppliers. Where possible, direct measurements of resolution and screen brightness were made through cooperation of the manufacturers. To further supplement available literature, demonstrations and briefings on a variety of equipment, notably storage and retrieval systems, were witnessed.

In the request for information, the contract was referenced and the nature and significance of the study was indicated. Of the 75 manufacturers to whom inquiries were directed, 30 responded with positive information. Several indicated that they were no longer involved in the area and the remainder failed to respond. A follow-up letter was sent to those who did not respond initially. This increased the return by approximately 20 percent.

The survey was designed to obtain a representative sample of currently available equipment. Failure to include a manufacturer or device in no way reflects upon either the maker or the equipment.

Summary of Microform Equipment

The results of the survey are presented in Tables 12 through 21. Tables 12 through 16 cover domestic equipment. Tables 17 through 21 cover devices of foreign manufacture. Addresses of the manufacturers are given on page 125.

TABLE 12

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Bell & Howell Co.	MASCOT (Portable)	11"x11" 500-hour ejection lamp.	21x (fixed)	COSATI and NMA fiche and jackets up to 6"x6"	7" high 13" wide 20" deep 16 lbs. 117 VAC 50/60 Hz 12 VDC		Built-in glare shield. Wall projection. Outlet adapter for remote 12 volt operation. Image rotation for 4"x6" fiche.
	HEADLINER	14"x14"	24x (fixed)	4"x6" pos./ neg. fiche 4"x6" jackets	24" high 16" wide 19" deep 38 lbs. 115 VAC 60 cycles		Image rotation 360 degrees.
	DUO	14"x20" 420 watt lamp	22x 30x (fixed)	to 6"x7⅜" COSATI, NMA, or TAB cards jackets EAM aperture cards	25⅜" high 20⅝" wide 17¼" deep 60 lbs. 117 VAC 50/60 Hz 5 amps AC only		At 22x, projects two 8½"x11" documents simultaneously. High-low illumination levels.

TABLE 12 (cont.)

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Bell & Howell Company (cont.)	1600 (Reader/ Filler)	8"x8" 21 volts, 150 watt halogen lamp	14.5x	16mm roll film in 100' length	20" high 20½" wide 20½" deep 70 lbs 115 VAC 50/60 Hz 1.5 amps		Projects, cuts, and files 16mm film in microfilm jackets. Cuts film exactly by exposing knife on screen. Variable brightness control.
DASA Corporation	PMR/50 (Portable)	8½"x11" 50 ft-L	20x 24x (fixed)	DoD, NMA, COSATI microfiche to 4"x6"	13" high 13" wide 7½" deep 7½ lbs. 115 VAC		Image resolution at center is 5.0 lpmm; covers, 4.5 lpmm. High-low illumination levels. Manual image rotation.
DatagraphiX	1325	11"x14" quartz iodine lamp with reflector and heat filter	24x 40x	4"x6" 3"x5" 3¼"x7⅜" microfiche & jackets	21" high 18" wide 22" deep	$240.00	
	1700			16mm film cartridge	21" high 18" wide 18" deep both models 115 VAC 50/60 Hz	$1269.00	
Eugene Dietzgen Company	4305	10½"x12" high intensity filament lamp	15x 20x	EAM aperture cards (DoD only)	23½" high 16" wide 19" deep 100-125 VAC 60 Hz 0.5 amps	$216.00 15x $248.00 20x	Swivel base for reader. Left hand operation models (4305-15L and 4305-20L).

TABLE 12 (cont.)

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	List Price	Special Features/ Accessories
Eugene Dietzgen Company (cont.)	4307 (Portable)	14"x14" low volt. high intensity filament lamp	17x 23x 30x 43x	16 mm or 35 mm roll	10" high 13" wide 11½" deep 17 lbs. 100-120 VAC 50/60 Hz 100 watts	$285.00 17x 23x / $315.00 30x 43x	Fold away viewing screen. Image rotation 360 degrees.
	4311	16"x16" 80 watt halogen lamp	27x	16 mm roll or cartridge 100' length	28" high 20" wide 28" deep 40 lbs. 100-125 VAC 60 Hz 4 amps	$545.00	Variable speed; electrically driven; high speed moves film through reader from 15-20 sec. per 100 feet.
	4313-A / 4313-AR	18"x24" 500 watt lamp	14.75x	A--aperture cards up to 5"x8" / AR--aperture cards and 35 mm roll film--100 ft	25" high 25" wide 29" deep 115 VAC 60 cycles 5 amps	A-- $715.00 / AR-- $750.00	Full "D" aperture card projected on screen.

TABLE 12 (cont.)

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Eugene Dietzgen Company (cont.)	4315	9½" ·12" low volt. high intensity lamp	19x 25x	up to 6"x6" aperture cards	23½" high 11¾" wide 15¼" deep 21 lbs. 117 VAC 50/60 Hz 1 amps	$178.00	
	4316	14"x20" 500 watts	22x 30x 42x	up to 6"x6" aperture cards and jackets	24½" high 20⅝" wide 18¾" deep 56 lbs. 117 VAC 50/60 Hz 5 amps	$400.00 22x 30x $420.00 42x	At 22x, two adjacent images projected simultaneously. Two-level intensity control.
	4317 4317-M	12"x12" low volt. high intensity filament lamp	20x	16 mm roll film or cartridges	22" high 15" wide 15" deep 100-125 VAC 60 cycles 4 amps	4317 $410.00 4317-M $466.00	4317-M with counter. Maximum speed at 15-20 sec. per 100 feet. Image rotation 90 degrees.

TABLE 12 (cont.)

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Eugene Dietzgen Company (cont.)	4319	9½"x12" low volt. high intensity filament lamp	19x 25x	to 4"x7⅜" microfiche and aperture cards	23½" high 11¾" wide 15¼" deep 21 lbs. 117 VAC 50/60 Hz 1 amp	$247.00	
	4314	10½"x12"	15x 20x	EAM aperture cards (DoD only)		$216.00 15x $248.00 20x	
	4303	12"x12"	17x 24x 30x 43x	16 mm and 35 mm roll film		$325.00 17x,24x $340.00 30x,43x	Image rotation 360 degrees.
DuKane Corp.	576-90	10½"x12" low volt lamp	15x	aperture cards			Image rotation 270 degrees.

TABLE 12 (cont.)

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
DuKane Corp. (cont.)	EXPLORER 14 27A25	14"x14" type FCR Tungsten halogen lamp	18x	16 and 35mm roll film aperture cards NMA and COSATI fiche 3"x5" and 4"x6" jacket	26" high 14¾" wide 18" deep 44 lbs. 115 VAC	$345.00	Special attachment for roll film. Image rotation 90 degrees. Variable brightness control.
	27A5	10"x13" DuKane 456-59 lamp, low voltage	20x	4"x6" micro-microfiche jacket film aperture cards roll film	24" high 12" wide 12" deep 22 lbs. 115 VAC	$160.00	Special attachment for microfiche and roll film. Image rotation 90 degrees. Variable brightness control.
Eastman Kodak Company	RECORDAK MOTORMATIC MPG	15"x15"	19x 23x	roll film	25¾" high 22⅞" wide 32" deep 70 lbs. 120 VAC 50/60 Hz 6 amps	MPG $1105. w/o lens kit	Provision for using indexed film. Printer, Model ERG available for both models ($940.00). Accepts magazines with special attachment.
	MPG-TH		29x 34x 43x			MPG-TH $1349. w/o lens kit lens kit $112.80 each	

TABLE 12 (cont.)

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Eastman Kodak Company (cont.)	RECORDAK STARMATIC Model PVM	9"x12"	20x 24x 32x 40x	16 mm roll film	19½" high 13¾" wide 12⅛" deep 27 lbs. 117 VAC 50/60 Hz	$618.45 w/o lens kit lens kit $65.80 each	Image rotation 270 degrees.
	RECORDAK STARLET Model FTA	10⅞"x12"	20x (fixed)	RECORDAK film mag. only	21½" high 14" wide 19½" deep 32 lbs. 117 VAC	$573.40	Adaptor to accommodate conventional 16 mm roll film.
	RECORDAK 310 Reader Model PVA	9"x12"	20x 24x 32x 40x	16mm roll film	19½" high 16" wide 11¼" deep 23 lbs. 117 VAC 50/60 Hz	$427.80 w/o lens kit lens kit $65.80 each	Image rotation 270 degrees.
	RECORDAK EASAMATIC Model PFCD		18.5x 21.5x 23x 25.5x 31x	DoD, NMA, and COSATI microfiche format to 3¼"x7⅜" and 4"x6"	19" high 19" wide 21" deep 20 lbs 120 VAC 50/60 Hz 2.5 amps.	$183.30 w/o lens kit and front glass lens kit $18.80 each	Dual image projection. Can view microfilm in cards and film jackets. Pointer locates each fiche instantly and projects.

TABLE 12 (cont.)

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Eastman Kodak Company (cont.)	RECORDAK Model PK-1013	10½"x13¼"	18x 23x	16mm film in jackets microfiche 3"x5" 4"x6" 5"x8" 3¼"x7⅜"	26⅜" high 12⅞" wide 18" deep 39 lbs. 115 VAC 50/60 Hz 0.5 amps 60 watts	$329.00 w/o lens kit lens kit $75.20 each	Image rotation 360 degrees.
	RECORDAK Model MKR-1 (Portable)	10½" x 12"	15x	aperture cards	21¼" high 12½" wide 13" deep 31 lbs. 115 VAC 50/60 Hz	$225.60	
	RECORDAK 1824 Model MKG-1	18"x24" 500 watt projector lamp	15x	aperture cards and roll film	28½" high 24 13/16" wide 28⅞" deep 100 lbs. 115 VAC 50/60 Hz 5 amps	$878.90	

TABLE 12 (cont.)

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Eastman Kodak Company (cont.)	RECORDAK MICROSTRIP Model PGR		17.5x 2.5x	film strips	20⅝" high 21¾" wide 28" deep 82 lbs. 117 VAC 50/60 Hz 2.9 amps	$817.80 w/o lens kit lens kit $75.20 each	Part of a microstrip retrieval station. Printer Model EG available for reader ($940.00).
	MICROSTAR PR-1		18-24x 21-28x 27-30x 34-45x	16mm roll film in magazine	21½" high 25¼" wide 38½" deep 140 lbs. 120 VAC 50/60 Hz	$1692. w/o lens kit lens kit $89.30 each	Magazine loading only, self threading. Zoom system available. Image rotation 360 degrees.
	RECORDAK LODESTAR Model PS-1K	13½"x13½"	23x	16mm roll film in magazine 100 ft. long	25" high 16½" wide 29" deep 90 lbs. 120 VAC 50/60 Hz	$1217. Model 4 Image Control Keyboard $4160.	Model IC-4 Image Control keyboard (random search of files on roll microfilm). Image rotation 360 degrees.

TABLE 12 (cont.)

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
GAF Corporation	D7504	11"x8½" horizontal quartz halogen lamp	18x 24x 32x	4"x5" 3¼"x7⅜" microfiche	15" high 19" wide 12" deep 25.5 lbs. 115 VAC 50/60 Hz 150 watts		Projects 11"x14" computer output images at 3/4 size. High-low illumination levels.
	7500	8½"x11" 550 hrs. 150 watt long life lamp	18x 24x	3"x5" and 4"x6" microfiche jacket	18½" high 9½" wide 16 " deep 110-120 VAC 50/60 Hz 1.5 amps	$109.65	
	7502	11½"x15½" 150 watt quartz halogen lamp	24x 42x	all standard microfiche and aperture cards	19" high 16½" wide 25" deep 110-120 VAC 50/60 Hz 1.5 amps	$225.25	Screen tilts 10 degrees. Computer format at 42x. Dual magnification (10x and 24x) available. High-low illumination levels

TABLE 12 (cont.)

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Itek Corporation	35 VM			roll or strip film			Variable illumination.
	AUTOFOCUS		from 23x to 36x autofocus	16mm and 35 mm film			Image rotation 360 degrees. Foot pedal permits high speed or scanning advance of film.
Keuffel & Esser Company	MICROMASTER 52 2035	15"x23" 150 watt lamp	4x	105 mm film	30" high 27" wide 28" deep 110 VAC 60 Hz 5 amps	$550.00	
	MICROMASTER 52 9949	8"x10"	6.5x 15x	aperture cards and 16mm or 35mm roll film	13" high 10" wide 15" deep 19 lbs. 115 VAC 60 Hz 1 5 amps		Roll film carrier optional equipment. At 6.5x, full view of doc.

TABLE 12 (cont.)

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Keuffel & Esser Company (cont.)	MICROMASTER 52-9921	14"x15"	24x	4"x7⅜" microfiche	25" high 18" wide 18½" deep 70 lbs. 115 VAC 60 Hz 3.5 amps		Displays 8½"x11" documents in full view.
	52-9923		30x	6"x8" microfiche			
	MICROMASTER 52-9922	14"x22"	24x	4"x7⅜" microfiche	25" high 23" wide 16½" deep 75 lbs. 115 VAC 60 Hz 3.5 amps		Displays two-8½"x11" documents or one-11"x17" document.
	52-9924		30x	6"x8" microfiche			
Micro Image Corporation	MICRA 210	11"x8½" 150 watt quartz halogen lamp 20 ft-c	18x 32x	4"x6" microfiche and jackets	16" high 13" wide 9" deep 12 lbs. 115 VAC 50/60 Hz	$129.00 18x $149.00 32x	Projects images on wall. Image resolution is 3.2 lppm with 2.8 lppm in frame. Image rotation: manual.
	MICRA 220		24x	16mm roll film in cartridge	16" high 12" wide 12" deep		

TABLE 12 (cont.)

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
3M Company	Series II 400 C	170 watt 20 volts quartz iodine w/ reflector		16mm roll film in cartridge	26½" high 17" wide 21⅓" deep 110 VAC 60 Hz 4 amps		Large screen attachment available to read computer data.
	FILMSORT Designer 184	18"x24" 300 watt 120 volts T-10-C13 base horiz (Sylvania)	15x	"D" aperture cards	31½" high 26" wide 27" deep 55 lbs.		Screen angled between 15 and 20 degrees. Image rotation 180 degrees. Designed to read engineering drawings.
	400		14.88x through 29x	standard types and format of pos. & neg. film	28½" high 17½" wide 22¾" deep 110 lbs. 90-130 VAC 60 Hz 10 amps		Retrieves images from a file of 10,000 images in seconds with digital keyboard input. Rewinds film automatically at end of search. Image rotation available.

TABLE 12 (cont.)

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
National Cash Register Co.	456-300 (Portable)	9½"x10½" quartz halogen lamp	18x through 38x interchange	3"x5" 4"x6" 3¼"x7⅜" microfiche	21" high 12½" wide 8½" deep 110 VAC 60 Hz		Image can be projected on wall.
	456-942	11½"x15" 150 watt silica halogen lamp	42x	up to 4"x6" microfiche	22" high 19" wide 21" deep 65 lbs. 110-120 VAC 50/60 Hz 160 watts		Image brightness variable. Can be modified to take 6"x8" microfiche.
	456-400	11"x11⅞" 100 watt silica halogen lamp	18x 24x special 21x	3"x5" 4"x6" 3¼"x7⅜" microfiche	21" high 16" wide 18" deep 35 lbs. 110-120 VAC 50/60 Hz 100 watts		Projects image on wall. Modified to take 6"x8" microfiche. Image brightness variable.
	456-800	13[illegible]" x 19¾" 150 watt high-silica halogen [illegible]	22x 26x 33x 38x	3"x5" 4"x6" 6"x6" microfiche	24" high 21½" wide 21½" deep 65 lbs. 110-120 VAC 50/60 Hz 160 watts		Dual page viewing. Pointer locates fiche and projects automatically.

TABLE 12 (cont.)

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
National Cash Register Co. (cont.)	455 PCMI	11"x11" 150 watt quartz halogen incand. lamp	150x	PCMI ultra-fiche, 4"x6"	26" high 16" wide 24" deep 60 lbs. 90-127 V 47-63 cps.		
NB Jackets Corporation	1600 (Reader/ Filler)	8"x8" quartz halogen lamp, 21 volts, 150 watts	14.5x	roll film into film jackets	20½" high 20" wide 20½" deep 70 lbs. 115 VAC 50/60 Hz 1.5 amps		Designed specifically for inserting single or multiple microfiche images into microfilm jackets. 700 strips per hour. Variable brightness control.
Taylor-Merchant Corporation	300 XF (Portable)	100 watts 110 volts CDS or CDX lamp		COSATI standard microfiche jackets	8" high 6" deep 3" wide 3 lbs.	$69.50	Projects images on wall. Adapters for COM format microfiche, 35mm color slides, and film strips.
	12 AMB	uses Ambient Light	12x	4"x6" 6"x8" microfiche	6 ounces	$15.95	Pocket microfiche viewer.
	16 AMB		16x			$17.95	
	12 X	battery operated	12x	microfiche	7 ounces standard pen-light batteries	$17.95	Pocket microfiche viewer.
	16 X		16x			$19.95	

TABLE 12 (cont.)

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Taylor-Merchant Corporation (cont.)	8 X		8x	4"x6" microfiche	1 ounce	$3.00	Pocket microfiche viewer.
	5 X		5x	aperture cards		$1.50	
	400	100 watt CDS or CDX lamp		aperture cards	6" high 3" deep 8" wide 3 lbs.	$79.50	Projects images on wall. Adapter to show color slides and film strips.
Teledyne Post Company	640	$11\frac{5}{16}$"x14"	18x 24x special 30x	up to 7.48"x7.88" microfiche and aperture card	$17\frac{1}{2}$" high 14" wide 15" deep 25 lbs. 115 VAC 50/60 Hz	$249.00	Lens: 36mm or 28mm. Four illumination settings.
VueTech Corp.	MULTIFOCUS	14.5"x20.5" CWA 120 volts 750 watts	10x to 40x variable	"D" aperture cards COSATI microfiche $6"x4\frac{1}{16}"$ film jackets	43" high 26" wide 29.5" deep 150 lbs.		Variable brightness control. Lens: 73mm for 10x to 20x; 38mm for 20x to 40x. Printer makes paper copies up to 14"x20".
	EXPEDITER	30"x42"		microfilm			Variable brightness control.

TABLE 12 (cont.)

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Washington Scientific Industries, Inc.	NORMANDALE 1518	15"x18" 24 volts 150 watt quartz halogen lamp	12.2x	aperture cards microfiche jackets	23" high 19" wide 20" deep 32 lbs. 110-120 VAC 50/60 Hz 200 watts		Two position brightness control.
	"C" (Portable)	9"x12" 12 volts 24 watts 300 hour lamp	20x special 24x	16mm-3M cartridge	19" high 13¾" wide 18½" deep 18 lbs. 110-120 VAC 50/60 Hz 3 AG fuse 5 amps		Optional batteries, 12 volts, 5 lbs; also auto cigarette lighter, 12 volts.
	"QS" (Portable)	10"x11" 12 volts 36 watts 300 hour lamp	6.5x full view 15x quadrant view	aperture cards	17½" high 13¾" wide 18½" deep 16 lbs. 110-120 VAC 50/60 Hz 5 amps		Optional batteries, 12 volts, 5 lbs; also auto cigarette lighter, 12 volts.
	"RM" (Portable) "RH" (Portable)	9"x12" 12 volts 24 watts 300 hour lamp	20x special 24x	16mm on 3" reel	19" high 13¾" wide 18½" deep 17 lbs. 110-120 VAC 50/60 Hz		Optional batteries, 12 volts, 5 lbs; also auto cigarette lighter, 12 volts.

TABLE 12 (cont.)

Survey of Microform Reader Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Washington Scientific Industries, Inc. (cont.)	"MF" (Portable)	9"x12" 12 volts 50 watt 300 hour lamp	20x special 24x	4"x6" microfiche and jackets	19½" high 13¾" wide 18½" deep 16 lbs. 110-120 VAC 50/60 Hz 5 amps		Optional batteries, 12 volts; weight, 3 lbs. Also adapts to 12 volt automobile lighter. Indexing grid card.
	NORTHSTAR 1	14"x14" quartz halogen lamp, 24 volts, 150 watts	24x	16mm film in 3M cartridges	22" high 16½" wide 25⅜" deep 110 VAC 50/60 Hz 400 watts		Variable brightness control. View computer output sheet. Resolution 4.5 lpmm.

TABLE 13

Survey of Microform Reader-Printer Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Accepted	Printing Process/ Output Copy	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Bell & Howell Company	530 D	11"x11"	15x 25x 35x (fixed)	16mm or 35mm roll film micro-fiche jackets	black&white silver print copies 8½"x11"	26" high 13" wide 30" deep 68 lbs. 110-120 VAC 60 Hz		Variable brightness control. Image rotation 360°. Makes copies in 8 sec. Special lenses: 10.5x, 13.4x, 20.1x, 27.9x, 33.8x, and 37x.
	REPORTER	11"x11" 500 hour lamp	18x 21x 24x (fixed)	COSATI & NMA fiche jackets up to 6" x 6"	electro-photographic paper prints 8½"x11" pos. print	29¼" high 18" wide 25" deep 145 lbs. 117 VAC 60 Hz		Rotation for 4"x6" size fiche and jacket. Makes copies in 8 sec.
	AUTOLOAD	14"x14"	zoom lens 20x to 40x	16mm roll film or cartridge	silver print paper copies 8½" x 11"	29½" high 22½" wide 34" deep 117 lbs. 117 VAC 60 Hz 3.5 amps		Lens continuously variable. Reader and printer purchased separately. Image rotation 360°. Prints made at any magnification. Three levels of brightness control.

TABLE 13 (cont.)

Survey of Microform Reader-Printer Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Accepted	Printing Process/ Output Copy	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Eastman Kodak Company	RECORDAK MAGNAPRINT PE-1A	11"x11"	11.8x 13.7x 17x 19x 22.5x 30x 38x	16mm or 35mm roll film aperture cards 2-channel jacket	automatic 8"x10" on 8½"x11 paper	29¼" high 16⅝" wide 27" deep 105 lbs. 117 VAC 50/60 Hz 300 watts	$1264.30 less lens kit lens kit $98.70 each	Accommodates magazine, aperture cards, film jackets, and microfiche with special attachment. Image rotation 270°. Makes copies in 28 sec
	RECORDAK PFC-1A		11.8x 13.7x 17x 19x 22.5x 30x 38x	micro-fiche aperture cards jackets		29¼" high 16⅝" wide 27" deep 100 lbs. 117 VAC 50/60 Hz	$1170.30 less lens kit lens kit $98.70 each	Prints produced at touch of button, in seconds.
Itek Business Corporation	18•24	18"x24"	14.5x	16 mm to 105 mm roll film or micro-fiche				Prints in 30 seconds.
	"RS"	18"x24"	14.5x	16mm or 35mm film	8"x18" to 18"x24"			Prints in less than 30 seconds. Makes up to 21 copies automatically; 4/min.

TABLE 13 (cont.)

Survey of Microform Reader-Printer Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Accepted	Printing Process/ Output Copy	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Keuffel & Esser Company	MICRO-MASTER 52-2038	18"x24" 150 watt 120 volts lamp	4x	4"x6" film		355 lbs. 115 VAC 60 Hz 5 amps	$4200.00	Printing time less than 20 seconds. Lamp intensity variable.
3 M Company	EXECUTIVE I	12"x12" 6 volts 39 watt lamp	20x 24x	sheet film up to 4"x8"	dry-silver paper prints 8½"x11"	25" high 19" wide 26" deep 40 lbs. 105-120 VAC 60 Hz 8 amps	$325.00	Prints in 30 seconds. Image resolution 3.5 to 4.0 lpmm with film of 10^ lpmm
	200			aperture card	12"x18" to 18" x24"	32" high 31" wide 36" deep 110 VAC 60 Hz		Excellent for engineering drawings.
	200 R	13" x24"		35mm film on reels sheet film aperture cards jackets micro-fiche	12" x18" to 18"x24"	33½" high 31½" wide 36½" deep 310 lbs. 110-120 VAC 15 amps		

TABLE 13 (cont.)

Survey of Microform Reader-Printer Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Accepted	Printing Process/ Output Copy	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
3M Company	400 (Large Screen)	14"x12"		microfilm	paper copies	26½" high 17" wide 21½" deep		Image rotation 360°. Copies in 6 seconds.
	400	200 watt 20 volts quartz iodine lamp with reflector		micro-fiche and jackets up to 5"x8"	dry paper copies 8½"x12½"	26½" high 17" wide 21½" deep 110 VAC 60 Hz 10 amps		Copies in 20 seconds.
	400 B 400 M	200 watt 20 volts quartz iodine lamp with reflector	6x 8x 10.5x 12x 15x 18x 21x 23x 29x 35x	16mm and 35 mm roll film aperture cards micro-fiche jacket 16mm and 35 mm roll film	8½"x11"	26½" high 17" wide 21½" deep 110 VAC 60 Hz 10 amps		Large screen attachment available. Copies in 6 seconds. Image rotation 360°.
	Series II 400 C			16mm film cartridge	8½"x11"			Copies in 6 seconds.

TABLE 13 (cont.)

Survey of Microform Reader-Printer Equipment (United States)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Accepted	Printing Process/ Output Copy	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
3M Company	400 F			micro-fiche jackets aperture cards to 6"x8"				Image rotation 90°.
	400 CT Series II	200 watt 20 volts quartz iodine lamp with reflector		16mm film cartridge	dry paper copy $8\frac{1}{2}$"x11"	$26\frac{1}{2}$" high 17" wide $21\frac{1}{2}$" deep 110 VAC 60 Hz 10 amps		Copies in 6 seconds. Handles Duo and Duplex imaged microfilm.
	500 CT	12"x16" 200 watt high-illumin. lamp	six lenses avail.	cartridge film	dry-silver paper copies $8\frac{1}{2}$"x11"	$31\frac{1}{2}$" high $18\frac{1}{4}$" wide $24\frac{3}{4}$" deep 140 lbs. 110 VAC 60 Hz 10 amps		Copies in 9 seconds. Image rotation 360°.
	500 M	200 watt high-illumin. lamp	ten lenses avail.	16mm and 35mm reel film aperture cards jackets fiche	dry-silver print paper $8\frac{1}{2}$"x11"	$31\frac{1}{2}$" high $18\frac{1}{4}$" wide $24\frac{3}{4}$" deep 140 lbs. 110 VAC 60 Hz 10 amps		Copies in 9 seconds. Image rotation 360°.

TABLE 14

Survey of Microform Camera Equipment (United States)

Manufacturer	Model No.	Type of Film	Reduct. Ratio	Input Copy	Operating Speed	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Bell & Howell Company	TAB-TRONIC	16mm roll film (daylight) 100' long	26:1	up to 15" wide	up to 5000 1/min	42" high 22" wide 11" deep 75 lbs. 115 VAC 60 Hz		Single sheet feeding attachment; also roll stock attachment. Computer printout. Exposure: automatic.
	DIRECTOR I		24:1 34:1 44:1	from checks to full size documents	600 checks/ minute 8000 full size doc. per hr.	12½" high 20½" wide 28½" deep 109 lbs. 115 VAC 60 Hz		Self-contained camera removable without exposing film in unit. Exposes two rolls of film simultaneously.
	MICROTWIN (205G and 205F Reader)	8mm and 16mm roll film	30:1 44:1 only 16mm film 24:1	up to 11" wide 2" to 15" long		43" high 32" wide 26" deep 125 lbs. 115 VAC 60 Hz		Reader uses camera lens for viewing processed film. Mag. of reader: 24x, 30x, and 44x. Exposure: automatic.
	210K	16 mm day-loading film on 100' roll	24:1 30:1 44:1	checks punch cards	28,000/ hour 380/min.	45" high 42" wide 23" deep 150 lbs. 115 VAC 60 Hz		Automatic feeder and stacker. Signer and endorser available.

TABLE 14 (cont.)

Survey of Microform Camera Equipment (United States)

Manufacturer	Model No.	Type of Film	Reduct. Ratio	Input Copy	Operating Speed	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Bell & Howell Company (cont.)	DIPLOMAT	105mm roll film 100 ft.	10:1 to 26:1 (variable)		1 sec. per exposure	8'2" high 7' wide 7' deep 600 lbs. 110-120 VAC 50-60 Hz 20 amps		Exposure: automatic.
Eastman Kodak Company	RELIANT 600 Model RW-1	16mm film in 100' or 200' roll	24:1 32:1 40:1 45:1			16½" high 24" wide 25½" deep 155 lbs. 117 VAC 50/60 Hz	$2870. plus film unit $837.	Interchangeable film units. Single or twin roll exposed simult. Indexer available.
	RELIANT 600K Model RW-1T	16mm film	24:1 32:1 40:1 45:1	51-col. or 80-column tab card	500 cards/ min.	17" high 24" wide 29" deep 168 lbs. 117 VAC 50/60 Hz	$5231. plus film unit $837.	Interchangeable film units for different reduction ratios. Twin roll exposure simultaneously is possible.
	RELIANT 400 Model RO-1	16mm film	20:1 32:1			15" high 25" wide 19" deep 75 lbs. 117 VAC 50/60 Hz 3 amps	$1697. plus film unit $555.	Interchangeable film units available. Single or twin roll exposed simult.

TABLE 14 (cont.)

Survey of Microform Camera Equipment (United States)

Manufacturer	Model No.	Type of Film	Reduct. Ratio	Input Copy	Operating Speed	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Eastman Kodak Company (cont.)	ROTOLINE Model RD-3		24:1 32:1	computer print-out up to 18" wide for 32:1 up to 14" wide for 24:1 up to 12" high	165 F.P.M. (or 12,000 lines of print-out data/min.)	61" high 29" wide 35" deep 310 lbs. 120 VAC 50/60 Hz 6 amps	$3567. plus film unit $784.	Interchangeable film units for different reduction ratios. Single or twin roll exposed simultaneously. Exposure: automatic.
	STARFILE Model RV-1		21:1	file card checks ID cards $4\frac{1}{4}$"x$11\frac{1}{2}$"	60/min.	12" high 16" wide 17" deep 22 lbs. 120 VAC 50/60 Hz	$343. plus film unit $249.	Interchangeable film units available. Lens ($89.30) required. Exposure: automatic. Operation: manual.
	STARFILE Model RV-2	16mm film 100' roll	22:1 27:1	up to $11\frac{1}{2}$"x15"	60/min.	37" high 29" wide 20" deep 45 lbs. 120 VAC 50/60 Hz	$550. plus film unit $249.	Interchangeable film units available. Exposure: automatic. Single or twin roll exposed simultaneously Lens ($89.30) required
	RECORDAK Model RP-1 (Portable)	16mm film 100' roll	20:1	any length, 12" wide	60/min. 125 checks/ min.	$6\frac{1}{2}$" high $15\frac{1}{2}$" wide $12\frac{1}{2}$" deep 24 lbs. 117 VAC 50/60 Hz	$1175. incl. film unit	Interchangeable film units available. Single or twin roll exposed simultaneously Adjustable illumin. for diff. exposure.

TABLE 14 (cont.)

Survey of Microform Camera Equipment (United States)

Manufacturer	Model No.	Type of Film	Reduct. Ratio	Input Copy	Operating Speed	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Eastman Kodak Company (cont.)	MICRO-FILE Model MRD-2	35mm film; 16mm film w/adapter	5:1 to 21:1	up to 26"x36¾"		102" high 72" wide 34" deep 165 lbs. 117 VAC 50/60 Hz	$3737. with film unit	Special attachment reduction ratio 27:1. Exposure: automatic.
	MICRO-FILE Model MRD-2/30	16mm film only	8:1 to 30:1	up to 17½"x30"			$3925. with film unit	Special attachment reduction ratio 36:1. Exposure: automatic.
	MICRO-FILE Model MRG-1	35mm film 100' roll	six preset ratios from 12:1 to 36:1	up to 45"x63"		9' high 9'8" wide 6'9" deep 975 lbs. 120/208 VAC 115/230 VAC 50/60 Hz 20 amps	$7849. with film unit	Interchangeable film units. Automatic and manual light levels. Exposure: automatic or manual.
	MIRACODE Model MRK-1	16mm film	8:1 to 30:1	up to 14"x22"		102" high 72" wide 34" deep 205 lbs. 117 VAC 50/60 Hz	$9870.	Records code on film for use with infor. retrieval systems. Exposure: automatic or manual.

TABLE 14 (cont.)

Survey of Microform Camera Equipment (United States)

Manufacturer	Model No.	Type of Film	Reduct. Ratio	Input Copy	Operating Speed	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Itek Business Products	3536		8:1 to 36:1	up to 45"x63"	2.5 sec.			Repeat cycling of any number of exposures. Exposure: automatic.
Keuffel & Esser Company	MICROMASTER 52-2020	35mm film 100' roll	12:1 16:1 20:1 24:1 30:1	up to 37½"x52½"		9'8" high 8'4" wide 6'0" deep 1040 lbs. 117 VAC 60 Hz 20 amps	$7052	Rotation of camera head 90 degrees. Special 60mm Zeiss lens available. Automatic 2-40 exp. available.
	52-2001	105mm-350' (optional 35mm-100')	105mm 4:1 to 11:1 (optional 35mm 12:1 to 36:1)	up to 44"x66"		11'2" high 9'5" wide 7'4" deep 1735 lbs. 115 VAC 60 Hz 20 amps	$ 12,950	Projects images. Magazines are interchangeable. Automatic-focusing point light source. Motor-driven filters.
3M Company	3400	16mm film cartridge			60/min.	12" high 26" wide 31" deep 115 VAC 50/60 Hz 3 amps		Up to 3000 documents on one cartridge.

TABLE 14 (cont.)

Survey of Microform Camera Equipment (United States)

Manufacturer	Model No.	Type of Film	Reduct. Ratio	Input Copy	Operating Speed	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
3M Company (cont.)	2000 E		16:1 24:1 30:1	up to 36"x48" (A to E size draw.)	40 sec. for compl. card	78" high 90" wide 44" deep 550 lbs. 100-130 VAC 60 Hz 15 amps		Processor-camera. Cartridge capacity is 500 film cards. Resolution: 16:1--113.6 lpmm, 24:1--120 lpmm, 30:1--135 lpmm.
	2000/P			up to 19"x26"	50 seconds for compl. card	32" high 39" wide 30" deep 450 lbs. 110-130 VAC 50 Hz 15 amps		Processor-camera. Positive film cards. Adapts to turret mounted lenses for various reductions. Cartridge capacity is 500 film cards.
	2000 Series II	card cartridge		up to 24"x36" (A to D size engin. drawing)	40 sec. for compl. card	61" high 72" wide 34" deep 600 lbs. 100-130 VAC 6 Hz 15 amps		Processor-camera. Cartridge capacity of 500 cards.

TABLE 15

Survey of Microform Developer/Processor Equipment (United States)

Manufacturer	Model No.	Type of Film	Film Capacity	Process. Speed	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Bell & Howell Company	SPECIALIST I	16mm	400' feed spool and 1000' take-up reel	18 ft/min. archival film 30 f.p.m. for non-archival film	53" high 65" wide 25" deep 450 lbs. 110-120 VAC 60 Hz 18 amps		Darkroom is not required for processing film. Audible signal for film feed.
	SPECIALIST II	16mm and 35mm					
	PROCESSOR (Three models for diff. size film)	two sheets of Diazo or Kalvar simultan.	(1) 3"x5" 4 1/16"x6" (2) 3 3/8 x 7 3/8" (3) 5 1/16" x8"	9-19 ft/ sec. adjusts for var. speeds of film	21" high 14 5/8" wide 19" deep 75 lbs. 110-115 VAC 60 Hz 6 amps		Fiche and jacket processor. Darkroom is not required for processing film.
CinTel Corp.	LM-SM	16mm and 35 mm	16mm: 2000' mag. 16/35mm: 1200' mag.	0-100 f.p.m.	55¼" high 8'10" wide 21" deep 915 lbs.; wet 1320 lbs 110-115 VAC 60 Hz 25 amps		Darkroom is not required for processing film.

TABLE 15 (cont.)

Survey of Microform Developer/Processor Equipment (United States)

Manufacturer	Model No.	Type of Film	Film Capacity	Process. Speed	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
CinTel Corp. (cont.)	LM-XM	16mm and 35mm	16mm: 2000' mag. 16/35mm 1200' mag.	0-100 f.p.m.	55¼" high 10'6" wide 21" deep 1070 lbs.; wet, 1675 lbs. 115/230 VAC 60 Hz 30 amps		Darkroom is not required for processing film.
	LM-70/ 105SN/P	up to 105 mm	500' long	0-50 f.p.m.	55¼" high 8'10" wide 21" deep 915 lbs.; wet, 1320 lbs. 115/230 VAC 60 Hz 30 amps		Darkroom is required for processing film.
	LM-70/ 105 XM	up to 105 mm	500' long	0-50 f.p.m.	55¼" high 10'6" wide 21" deep 1070 lbs.; wet, 1675 lbs. 115/230 VAC 60 Hz 30 amps		Darkroom is required for processing film.

TABLE 15 (cont.)

Survey of Microform Developer/Processor Equipment (United States)

Manufacturer	Model No.	Type of Film	Film Capacity	Process. Speed	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
CinTel Corp. (cont.)	LM-SN/P	16mm and 35mm	16mm: 2000' mag. 16/35mm: 1200' mag.	0-100 f.p.m.	59" high 8' wide 21" deep 840 lbs.; wet,1130 lbs. 115/230 VAC 60 Hz 25 amps		Darkroom is not required for processing film.
	LM-XN/P	16mm and 35mm	16mm: 2000' mag. 16/35mm 1200' mag.	0-100 f.p.m.	59" high 9'8" wide 21" deep 990 lbs.; wet,1480 lbs. 115/230 VAC 60 Hz 30 amps		Darkroom is not required for processing film.
Eastman Kodak Company	PROSTAR DVR	16mm and 35mm	2-100 ft.	5 f.p.m.	$28\frac{1}{2}$" high 25" wide $12\frac{1}{2}$" deep less than 100 lbs. 117 VAC 60 Hz 15 amps	$3224.20 w/o processing rack	Process two films (16mm) simultaneously with accessories. Darkroom is not required for processing film.

TABLE 15 (cont.)

Survey of Microform Developer/Processor Equipment (United States)

Manufacturer	Model No.	Type of Film	Film Capacity	Process. Speed	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Eastman Kodak Company (cont.)	VISCOMAT Model 36	16mm	1200 ft.	36 f.p.m.	470 lbs. 117 VAC 60 Hz 30 amps	$15.040.00	Extra film chambers available.
Itek Business Products	335 Transflo	16mm to 105mm					Universal and dual mag. available to expand output Process simultaneously 4 rolls of 16mm film or 3 rolls of 35mm. Darkroom not required.
Keuffel & Esser Company	52-2049	up to 105mm	up to 350 ft.	5 f.p.m.	5' high 64" wide 21" deep 160 lbs. 115 VAC 60 Hz 1200 watts	$2546.00	Darkroom not required.

TABLE 16

Survey of Microform Duplicator Equipment (United States)

Manufacturer	Model No.	Input--Type of Film	Duplicat. Rate	Dimensions/Weight/Power	Base Price	Special Features/Accessories
Bell & Howell Company	PRINTER	microfiche and jackets up to 5"x8"	500 sheets of Kalvar or Diazo per hour	16" high 21" wide 23" deep 90 lbs. 110-115 VAC 60 Hz 6 amps		Precision 400 watt metal halide QVC, ultraviolet lamp system. Variable exposure control.
Blu-Ray, Inc.	909 (Portable)	microfiche aperture cards strip-to-strip roll-to-roll strip-to-roll paper print up to 11" wide	5-16 f.p.m average speed with diazo mat. 5 f.p.m.	$11\frac{1}{8}$" high 27" wide $15\frac{1}{4}$" deep 99 lbs. 220 VAC 50 Hz	$1620.00	Can be used as a white printer.
DatagraphiX	3500	Kalvar microfilm	10 sec./print	33" high 22" wide 22" deep 115 VAC 50/60 Hz 5 amps	approx. $1400.00	Paper prints available in positive to negative; negative to positive; positive to pos.; and negative to negative. Sizes are 11"x$8\frac{1}{2}$" or 11"x14".

TABLE 16 (cont.)

Survey of Microform Duplicator Equipment (United States)

Manufacturer	Model No.	Input--Type of Film	Duplicat. Rate	Dimensions/Weight/Power	Base Price	Special Features/Accessories
DatagraphiX (cont.)	92	16mm or 35mm roll	10-60 f.p.m.	19" high 34" wide 23" deep 145 lbs. 115 VAC 60 Hz 20 amps	$6580.00	No darkroom required. Table top machine.
	96	105mm film up to 250'	10-60 f.p.m.	70" high 44" wide 27" deep 1100 lbs. 220 volts 3-phase 60 Hz 20 amps	$18,800.	Floor mounted machine. No darkroom required.
Extek Micro-systems, Inc.	3000	16mm and 35mm film	up to 320 f.p.m.	$29\frac{3}{4}$" high $40\frac{1}{4}$" wide $20\frac{1}{8}$" deep ?05 lbs. 118 VAC o0 Hz 15 amps	$3450.00 w/o vacuum heads	
	1050	16mm to 105mm film	up to 320 f.p.m.		$6650.00 w/o vacuum heads	

TABLE 16 (cont.)

Survey of Microform Duplicator Equipment (United States)

Manufacturer	Model No.	Input--Type of Film	Duplicat. Rate	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Extek Micro-systems, Inc. (cont.)	1635	silver film 16mm and 35mm	up to 300 f.p.m.	30" high 41" wide 21" deep 200 lbs. 110-130 VAC 50/60 Hz	$5695.00	Merging duplicator. Sequence density programmer. Automatic counter. Darkroom required.
Itek Business Products	303	16mm, 35mm, and 70mm film				Can be converted with color filters to make contact color prints. Darkroom is required.
	OP-60/61	film card				OP-61 automatic repeater, up to 99 cards automatically. OP-60 manual operation.
	OP-30	film card	750/hr.			Automatically makes from 1-99 copies of a single card.
GAF Corporation	FP-2	16mm or 35mm up to 1000' roll	30 f.p.m.	27" high 42½" wide 24¾" deep 230 lbs. 115 VAC 60 Hz 10 amps	$3145.50	400 watt lamp. Diazo method. Darkroom is not required for duplicating film.

TABLE 16 (cont.)

Survey of Microform Duplicator Equipment (United States)

Manufacturer	Model No.	Input--Type of Film	Duplicat. Rate	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
GAF Corporation (cont.)	CBS Model 303	16mm or 35mm 1000' roll	50 f.p.m.	65" high 59" wide 28" deep 840 lbs. 110/120 VAC 35-40 amps	$11,995.	Exposes, develops, and rewinds film in one continuous cycle. Diazo method. Darkroom is not required.
	CBS Model 1500	16mm or 35mm 1000' roll	150 f.p.m.	73" high 41" wide 28" deep 950 lbs. 220 VAC 35-40 amps	$16,127.	Exposes, develops, and rewinds film in one continuous cycle. Diazo method. Darkroom is not required.
Keuffel & Esser Company	MICROMASTER 52-9954	16mm or 35mm film card	8 aperture cards/min.	38" high 30" wide 15" deep 80 lbs. 115 VAC 60 Hz 5 amps		Semi-automatic card-to-card or roll-to-card copying.
	52-9965	16mm or 35mm film card	8 aperture cards/min.	48" high 30" wide 18" deep 110 lbs. 115 VAC 60 Hz 5 amps		Semi-automatic card-to-card or roll-to-card copying.

TABLE 16 (cont.)

Survey of Microform Duplicator Equipment (United States)

Manufacturer	Model No.	Input--Type of Film	Duplicat. Rate	Dimensions/Weight/Power	Base Price	Special Features/Accessories
Keuffel & Esser Company (cont.)	MORGAN 37	105mm film converts to 35mm up to 350' long		36" high 69" wide 34" deep 1200 lbs. 115 VAC 25 amps		Reduction ratio, approximately 3.6x; between 4x and 1.5x, preset at factory.
3M Company	DUPLI-PRINTER	aperture cards (silver diazo or thermal)	8 cards/min.	30" high 38" wide 15" deep 82 lbs. 115 VAC 60 Hz 5 amps		Negative-to-negative or positive-to-positive printing. Adjustable exposure range control.
	333 (Dry Silver Printer)	aperture cards	up to 8 cards/min.	29¼" high 61" wide 29" deep 350 lbs. 105-125 VAC 60 Hz		Paper prints only--up to 25 copies of one card automatically. Up to 18"x24" print.

TABLE 16 (cont.)

Survey of Microform Duplicator Equipment (United States)

Manufacturer	Model No.	Input--Type of Film	Duplicat. Rate	Dimensions/Weight/Power	Base Price	Special Features/Accessories
NB Jackets Corporation	404 (Printer)			16" high 21" wide 23" deep 90 lbs. 110-115 VAC 60 Hz 6 amps		
	404 (Processor)	3"x5" $4\frac{1}{16}$"x6"	400 Kalvar or Diazo sheets per hour 9 sec/cycle	21" high $14\frac{5}{8}$" wide 19" deep 75 lbs. 110-115 VAC 60 Hz 6 amps		
	407 (Processor)	$3\frac{3}{8}$"x$7\frac{3}{8}$"				
	408 (Processor)	$5\frac{1}{6}$"x 8"				
Teledyne Post	610	aperture cards	8/min.			

TABLE 17

Survey of Microform Reader Equipment (Foreign Manufacturers)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Fuji Photo Film Company, Ltd.	R 812 (Portable)	21x29.7 cm 12 volts 50 watt Halogen lamp	7.5x 17.7x	aperture cards	18" high 16½" wide 13" deep 12 kg. 100 VAC 70 watts		Roll film adapter available for 35mm film.
	R 1824	18"x24" 24 volts 120 watt point filament lamp	15x	35mm film 100' roll aperture cards strip film	30½" high 29" wide 26¾" deep 200 watts maximum		
	RFP 1 (Portable)	30x30 cm	20x	microfiche maximum 105x150mm aperture cards	19.7" high 15" wide 17" deep in use 8.5 kg. approx. 19 lbs. 100 VAC 50/60 Hz 100 watts		

TABLE 17 (cont.)

Survey of Microform Reader Equipment (Foreign Manufacturers)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
MICROBOX	MLK 4	8½"x12" 24 volts 150 watt halogen lamp	7.4x partial detail 14.8x	aperture cards microfiche roll film	41 cm high 34 cm wide 48 cm deep 26 lbs. 220/110 V 50/60 Hz		
	MLK 3	12½"x17" (A 3) 24 volts 150 watt halogen lamp	10.5x partial detail 21x	aperture cards microfiche roll film	50 cm high 46 cm wide 50 cm deep 31 lbs. 220/110 V 50/60 Hz		
	MLK 2	17"x24" (A 2) 24 volts 150 watt halogen lamp	14.8x partial detail 29.7x	aperture cards microfiche roll film	62 cm high 64 cm wide 60 cm deep 42 lbs. 220/110 V 50/60 Hz		
	MLK 1	24"x33½" 24 volts 150 watt halogen lamp	21x partial detail 42x	aperture cards microfiche roll film	89 cm high 89 cm wide 73 cm deep 64 lbs. 220/110 V 50/60 Hz		

TABLE 17 (cont.)

Survey of Microform Reader Equipment (Foreign Manufacturers)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Proti Micro Reader Corp.	UNIVERSAL P 1 (Portable)	25x34 cm 12 volts 50 watt quarter sized halogen lamp	17.5mm for 16mm film 22.5mm for 35mm film 37.5mm 42.5mm for 35mm film and slides	16mm and 35mm film microfiche jackets aperture cards 5x5 slides	36 cm high 27 cm wide 10 cm deep 6.2 kg. 220/110 V	approx. $118.00 each lens $22.00	
	P 3	42x59.4cm 12 volts 100 watt halogen lamp	14.8x 21x 29.7x			approx. $410.00 incl. lens	
	P 4	42x59.4cm (A 2 format--approx. 17"x24")		16mm and 35mm film microfiche jackets aperture cards 5x5 slides		approx. $225.00 incl. lens	

TABLE 17 (cont.)

Survey of Microform Reader Equipment (Foreign Manufacturers)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Heinz Zeutschel Gerätebau KG	445K 445R	31x44 cm (A 3) 12 volts 100 watt halogen lamp	10.5x 14.8x 21x 26x 29.7x	K-- aperture cards R-- 16mm and 35mm roll film	59 cm high 49 cm wide 76 cm deep 16 kg. 220 volts 50 Hz		Image rotation upon request. Up to three lenses in turret.
	605K 605R	44x60.5cm (A 2) 12 volts 100 watt halogen lamp	10.5x 14.8x 21x 26x 29.7x	K-- aperture cards R-- 16mm and 35mm roll film	71 cm high 66 cm wide 76 cm deep 16 kg. 220 volts 50 Hz		Image rotation upon request. Up to three lenses in turret.
	SYSTEMATIC 600	44x60 cm halogen	14.8x 21x 29.7x	16mm and 35mm film aperture cards microfiche	142 cm high 74 cm wide 109 cm deep 95 kg. 110/220 V		Available with hard copy facility with build-in "repro port" processor. Special lenses: 16x, 24x, and 35x.
	610K 610R	42x59.4 cm 12 volts 100 watt halogen lamp	14.8x	K-- aperture cards R-- 16mm and 35mm roll film	63 cm high 64 cm wide 59 cm deep 11 kg. 110/220 V 50 Hz		

TABLE 17 (cont.)

Survey of Microform Reader Equipment (Foreign Manufacturers)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Heinz Zeutschel Gerätebau KG (cont.)	450K	29.7x42 cm 12 volts 100 watt halogen lamp	10.5x	K-- microfiche	51 cm high 47 cm wide 49 cm deep 11 kg. 110/220 V 50 Hz		
	450R			R-- 16mm and 35mm roll film			
	SYSTEMATIC 340	34x30 cm quartz iodine lamp	26x	aperture cards microfiche	56 cm high 40 cm wide 65 cm deep 27 kg. 110/220 V 100 watts		Special lenses: 18x, 23x, and 40x.
	MP 2	31x31 cm 12 volts 100 watt lamp	8x 10x 13x 16x 20x	aperture cards microfiche	60 cm high 50 cm wide 68 cm deep 62 kg. 220 volts 50 Hz		Roll film attachment available. Screen slants 30 degrees.
	MP 2 VARIO	31x31 cm 12 volts 100 watt lamp	6.5-8.7x 8.7-11.2x 10.4- 13.5x	aperture cards microfiche	75 cm high 50 cm wide 72 cm deep 75 kg. 220 volts 50 Hz		Roll film attachment available.

TABLE 17 (cont.)

Survey of Microform Reader Equipment (Foreign Manufacturers)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Size Accepted	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Heinz Zeutschel Gerätebau KG (cont.)	MP 3	32x90 cm 150 and 250 watt quartz iodine lamp	10x	16mm film 35mm film 70mm film	93 cm high 97 cm wide 52 cm deep 87 kg. 110/220 V 115/240 V		Other lenses upon request. Table top viewer.

TABLE 18

Survey of Microform Reader-Printer Equipment (Foreign Manufacturers)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Accepted	Printing Process/ Output Copy	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Fuji Photo Film Company, Ltd.	Q 4 A	8¾"x11¾" 24 volts 150 watt halogen lamp	6.7x 8.7x 12.5x 13.7x 20x 23x 26.4x	16mm and 35mm film strip film aperture cards micro-fiche	paper print 8"x11"	33½" high 23¼" wide 20½" deep 68 kg. 100 VAC 50/60 Hz		Rotation of image 360° Copies made in 12 sec. Screen angled 8°.
	Q 4 AC			16mm cartridge				
	Q 215	18"x24"						Ideal for engineering drawings.
	Q 4 AS	30x30 cm 24 volts 150 watt halogen lamp	6.7x 8.7x 12.5x 13.8x 20x 23x 26.4x	16mm and 35mm roll film micro-fiche jackets aperture cards	paper print 21x29.7 cm	78 cm high 64 cm wide 52 cm deep 70 kg. 100 volts 300 watts		Image rotation 360°. Exposure fully automatic; copies in 10 seconds. Interchangeable lenses.

TABLE 18 (cont.)

Survey of Microform Reader-Printer Equipment (Foreign Manufacturers)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Accepted	Printing Process/ Output Copy	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
MICROBOX	RP 234	17"x24" 15 volts 150 watt halogen lamp	14.8x 10.5x 7.4x	aperture cards film strips roll film	electro-static proc. on zinc oxide paper same size as view or enlarged (A2,3, & 4)	152 cm high 210 cm wide 94 cm deep 550 lbs. 220 volts 50 Hz 2200 watts		Print in 15 sec. Prints 120/hr. Positive to positive prints also.
	RP 2		14.8x					
Proti Micro Reader Corp.	DALCO A 3			16mm and 35mm film micro-fiche aperture cards slides 5x5	paper prints 21x29.7 cm (A 4) 29.7x42 cm (A 3)		$600.00	No darkroom required. Prints in less than 1 minute. Positive to positive prints also.
Heinz Zeutschel Gerätebau KG	RS 3	31x44 cm halogen lamp	10.5x 14.8x 18x 21x 27x 29.7x 32x 38x	roll film aperture cards micro-fiche	paper prints approx. 30x44 cm (A3 and A4)	75 cm high 97 cm wide 117 cm deep 150 kg. 110/220 V 50 Hz	approx. $240.00	Interchangeable lenses. Automatic exposure/ copies 200/hr. Other lenses upon request.

TABLE 18 (cont.)

Survey of Microform Reader-Printer Equipment (Foreign Manufacturers)

Manufacturer	Model No.	Screen Size/ Brightness	Magnif.	Film Accepted	Printing Process/ Output Copy	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Heinz Zeutschel Gerätebau KG (cont.)	3K	29.7x42 cm halogen lamp	8.5x 10.5x 11x 14.8x 18x 21x 26x 29.7x 40x	16mm and 35mm roll film aperture cards micro-fiche jackets	paper print up to A3	71 cm high 56 cm wide 50 cm deep 52.5 kg. 110/220 V		Copies in 10-40 sec. Interchangeable film transport system.
	2K	45x60 cm halogen lamp	14.8x 16x 21x 24x 29.7x 35x	16mm and 35mm film aperture cards micro-fiche jackets	paper prints from A2 to to A6	142 cm high 160 cm wide 109 cm deep 175 kg. 110/220 V		Interchangeable film transport system. Copies in 10-40 sec.

TABLE 19

Survey of Microform Camera Equipment (Foreign Manufacturers)

Manufacturer	Model No.	Type of Film	Reduct. Ratio	Input Copy	Operating Speed	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Agfa-Gevaert	COPEX D4000	16mm	23:1 simplex 34:1 45:1 simplex, duo, and duplex	up to $8\frac{1}{4}$"x$11\frac{3}{4}$" (A4)	130 f.p.m.	16" high 25" wide 24" deep 88 lbs. 220 volts 50 Hz 600 watts		Two rolls simult.; interchangeable film units. Exposure: manual or automatic.
Cameronics, Ltd.	M.F. 10	micro-fiche	20x		12 compl. fiche/hr. (60 doc. on each fiche)			Resolution: 140 lpmm; maximum 180 lpmm at 20x. Exposure: automatic. No darkroom required.
Fuji Photo Film Co., Ltd.	L 2	35mm film 100' long	12x to 30x (auto.)	up to 37.8" x53.1"	39 frames/ min.	8'11" high 10'5" wide 6'1" long 100-120 V		Special attachment for 16mm film. Resolution: 120 lpmm at 30x. Exposure: automatic. Lens: M56mm f/7.3.
	M 2	35mm film 100' long	4x to 21x (auto.)	up to 26.4"x 37.2"	46 frames/ min.	103.5" high 104" wide 58.2" long 270 kg. 100-120 V		Special attachment for 16mm film. Exposure: automatic. Lens: M77mm f/8 fix.

TABLE 19 (cont.)

Survey of Microform Camera Equipment (Foreign Manufacturers)

Manufacturer	Model No.	Type of Film	Reduct. Ratio	Input Copy	Operating Speed	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Fuji Photo Film Co., Ltd. (cont.)	S 2	35mm	5x to 14x (manual)	17.6"x 24.8"	46 frames/ min.	56.8" high 59.1" wide 28.4" deep 72 kg. 100-120 V 50/60 Hz		Exposure: semi-auto. Lens: M77mm f/8 fix. Special attachment for 16mm film.
MICROBOX	MBS-0 MB-0	35mm 100' long	6-30x or 6-34x (auto)	30x 84x120cm 34x 95.2x 136cm		285 cm high 3[illegible]5 cm wide 170 cm deep 840 lbs. 220 volts 50 cps. 3.5 Kw		Exposure: automatic meter.
	MB-1	35mm 100' long cassette	7-21x	67.2x 94.5cm		225 cm high 250 cm wide 145 cm deep 460 lbs. 220 V 50 Hz		
	MBS-1	35mm 100' long cassette	6-21x	67.2 x 94.5cm		230 cm high 235 cm wide 130 cm deep 550 lbs. 220 volts 50 Hz		

TABLE 19 (cont.)

Survey of Microform Camera Equipment (Foreign Manufacturers)

Manufacturer	Model No.	Type of Film	Reduct. Ratio	Input Copy	Operating Speed	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Heinz Zeutschel Gerätebau KG (cont.)	SYSTEMATIC 111	35mm	14.8x 21x	A1 (D size)	900/hr.	90 x 180cm 120 kg. 220 volts 50 Hz 1600 watts		Other reduction ratios available.
	SYSTEMATIC 112	35mm	14.8	A2 (C size)	900/hr.	90 x 180cm 120 kg. 220 volts 50 Hz 1600 watts		

TABLE 20

Survey of Microform Developer/Processor Equipment (Foreign Manufacturers)

Manufacturer	Model No.	Type of Film	Film Capacity	Process. Speed	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Fuji Photo Film Co., Ltd.	AUTO-PROCESSOR 2	16mm and 35mm 100' long	100' roll	80cm/min. 45 min./ 100' roll	44" high 47.6" wide 14.6" long 240 lbs. 100 VAC 50 or 60 Hz		
	S 105 B (Camera/ Processor)	105mm x 148.75mm (sheet film)		(filming) 30 frames /min. (110 sec. w.titles) (process) 6 min.	66" high 55" wide 35½" deep 100/240 V		Reduction ratios: 16x to 24x automatically Exposure: automatic. Input copy: 38.4 x 55.2 cm.
MICROBOX	T 35/5	35mm film strips	5 strips		50 cm high 70 cm wide 23 cm deep 9 kg. 220 volts 0.5 Kw		No darkroom required.
	T 35/10		10 strips				
	R 3516 K	roll film strip film 16mm and 35mm	cassettes	60meter/hr	62.5 cm high 85.5 cm wide 32.5 cm deep 40 kg. 220 volts		No darkroom required.

TABLE 21

Survey of Microform Duplicator Equipment (Foreign Manufacturers)

Manufacturers	Model No.	Input--Type of Film	Dupli at. Rat	Dimensions/ Weight/ Power	Base Price	Special Features/ Accessories
Heinz Zeutschel Gerätebau KG	SYSTEMATIC 100	16mm and 35mm film 100' roll magazine		45.4 cm high 49 cm wide 29.2 cm deep 22 kg. 110/220 V 50 Hz		Automatic feeding. Adjustable illumination control. No darkroom required.
	SYSTEMATIC 100L	16mm and 35mm film 100' roll magazine		45.4 cm high 61.8 cm wide 29.2 cm deep 30 kg. 110/220 V 50 Hz		Visual control from original film. Automatic feed. Adjustable illumination control.
	SYSTEMATIC 100 SA	16mm and 35mm film 100' roll magazine		45.4 cm high 61.8 cm wide 29.2 cm deep 39 kg. 110/220 V 50 Hz		Provides visual control with selection capability to select sections of original film. Adjustable illumination control.

LIST OF UNITED STATES MANUFACTURERS

BELL & HOWELL COMPANY
Micro Data Division
6800 McCormick Road
Chicago, Ill. 60645

BLU-RAY, INC.
Essex, Connecticut 06426

CINTEL CORPORATION
11801 West Olympic Blvd.
Los Angeles, Calif. 90064

DASA CORPORATION
15 Stevens Street
Andover, Massachusetts 01810

DATAGRAPHIX
P.O. Box 2449
San Diego, Calif. 92112

EUGENE DIETZGEN COMPANY
2425 North Sheffield Avenue
Chicago, Illinois 60614

DU KANE CORPORATION
103 North 11th Street
St. Charles, Illinois 60174

EASTMAN KODAK COMPANY
919 Culver Road
Rochester, N.Y. 14609

EXTEK MICROSYSTEMS, INC.
15424 Cabrito Road
Van Nuys, Calif. 91406

LIST OF UNITED STATES MANUFACTURERS (cont.)

GAF CORPORATION
140 West 51st Street
New York, N.Y. 10020

ITEK BUSINESS PRODUCTS
1001 Jefferson Road
Rochester, N.Y. 14603

KEUFFEL & ESSER COMPANY
20 Whippany Road
Morristown, New Jersey 07960

3M COMPANY
Microfilm Products Division
St. Paul, Minnesota 55101

MICRO IMAGE CORPORATION
11436 Sorrento Valley Road
San Diego, Calif. 92121

THE MOSLER SAFE COMPANY
Information Systems Division
Hamilton, Ohio 45012

NB JACKETS CORPORATION
54-18 - 37th Avenue
Woodside, New York 11377

THE NATIONAL CASH REGISTER COMPANY
Industrial Products
3100 Valleywood Drive
Dayton, Ohio 45429

RANDOMATIC DATA SYSTEMS, INC.
344 West State Street
Trenton, New Jersey 08618

LIST OF UNITED STATES MANUFACTURERS (cont.)

SANDERS-DIEBOLD, INC.
Daniel Webster Highway
Nashua, New Hampshire 03060

THE TAYLOR-MERCHANT CORPORATION
25 West 45th Street
New York, N.Y. 10036

TELEDYNE POST
Frederick Post Company
P. O. Box 803
Chicago, Ill. 60690

VUE TECH
422 Industrial Drive
Maryland Heights, Missouri 63043

WASHINGTON SCIENTIFIC INDUSTRIES, INC.
Long Lake, Minnesota 55356

LIST OF FOREIGN MANUFACTURERS

Home Office Address	U.S. Representatives
AGFA-SEVAERT, INC. West Germany	AGFA-GEVAERT, INC. 275 North Street Teterboro, New Jersey 07608
CAMERONICS, Ltd. Microform Division Athlon Road Alperton, London, England	
MICROBOX Dr. Welp GmbH & Co. P.O. Box 143 D-635 Bad Nauheim West Germany	
FUJI PHOTO FILM COMPANY, INC. 26-30 Nishiazabu Z-chome Minato-ku, Tokyo 106 Japan	FUJI PHOTO FILM COMPANY, INC. 350 Fifth Avenue New York, N.Y. 10001
N.V. PROTI MICRO READER CORPORATION Stijn Buijsstraat 4a Postbox 110 Nijmegen, Holland	

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Brightness and Resolution of Commercial Microform Readers

Most sales and promotional literature obtained in the equipment survey contained no specific information on screen brightness or resolution. To obtain an estimate of what industry has to offer, we obtained the gracious cooperation of two manufacturers, Eastman Kodak Company and 3M Company, who permitted us to take measurements on a variety of their equipment.

The purpose of taking the measurements was not to evaluate or compare these manufacturers but to determine the general range of screen brightness and resolution available in the marketplace.

The equipment measured was demonstration gear, and while it was in good working condition, no special adjustments had been made. In some instances, performance might be improved through adjusting the optical system but company representatives agreed that the devices were representative in their present condition.

Resolution was measured by inserting a Standard Air Force Tri-Bar pattern in the form of a 35mm, positive transparency into the reader and examining the pattern on the screen using an eye-loop (4x).

Brightness measures were made with an SEI photometer accurate to 0.1 log unit.

The results are summarized in Table 22. It may be seen that resolution ranged from a low of 181 to a high of 456 lines/mm. Maximum screen brightness ranged from 15 to 90 ft-L and average screen brightness ranged from 9 to 56 ft-L.

Overall, it would appear that the resolution of these systems is quite good and that the limiting factor would be the resolution of the input film and not the reader.

TABLE 22

Sample Display Resolution and Screen Brightness
of Microform Readers

3M Company

Model No.	Resolution at Center of Screen (lines/mm)	Maximum Screen Brightness and Average of Center and four Corners (ft-L)	
		Maximum	Average
Model 400 M (roll film or flat format with attachment)	362	48	43
Model 400 CT Reader-Printer	456	63	30
Model 400 CT (Wide Screen) for computer printout work	456	40	40
Model 500 FASTBACK Reader (Replaces 400 LR)	362	50	46
Model 400 Page Search Reader Printer	406	55	52
Executive I (low cost reader-printer for cards and fiche)	228	15	9
Model 200 Reader-Printer	228	48	45

TABLE 22 (cont.)

Sample Display Resolution and Screen Brightness of Microform Readers

Eastman Kodak Company

Model No.	Resolution at Center of Screen (lines/mm)	Maximum Screen Brightness and Average of Center and four Corners (ft-L)	
		Maximum	Average
MOTORMATIC Reader-Printer	300	75	56
STARMATIC, Model PVM	286	90	53
LODESTAR PS 1K	202	32	24
LODESTAR PEK 1 (used in Miracode System)	322	90	39
MAGNAPRINT Reader PE-1A (Multipurpose Reader)	256	45	35
EASAMATIC PFCD (Fiche Reader)	181	32	25

Only one or two of these devices had brightness adjustments. Generally, the brightness adjustment is accomplished by changing voltage to the projection lamp in the form of one to three discrete steps. Most readers have no brightness adjustment whatever and most have little or no provision for glare shielding.

Perhaps 80 percent of the readers examined used "no-glare" screens. The remainder had a polished surface which tended to image extraneous light sources. This can be distracting and may reduce legibility.

Microform Retrieval Systems

There are many different types of microform retrieval systems. They range from simple manual devices to highly sophisticated, computer operated systems. The systems may be categorized as manual, semi-automatic, and fully automatic. The four systems described below serve to illustrate the functions and range of capabilities available today in the microform industry. The examples were chosen to indicate the kinds of systems that exist and their inclusion is not to be construed as an endorsement in any form.

Manual Systems

At the most rudimentary level, information retrieval is strictly manual. The user maintains a file of film rolls, fiche, or aperture cards, and retrieves and refiles the data manually. Any of a hundred different readers may be used to display the information.

Semi-automatic Retrieval Systems

As defined here, semi-automatic refers to a system which may be accessed by means of an electronic or electromechnaical keyboard. By inputing the proper numbers or alphanumeric descriptors, the desired fiche or card is

automatically selected and presented to the user for insertion into a viewer. This card or fiche is manually refiled after use.

Randomatic. One system of this type is the "Randomatic" produced by Randomatic Data Systems, Inc., Trenton, New Jersey. As its name implies, access to the card file is random. There is no need to file cards in any order. Cards may be retrieved singly or in groups.

The cards are coded by notching along the bottom edge. This is accomplished in a few seconds by merely placing the card in a built-in, electrically operated punch and indexing its identification. Cards include standard tab size (3-1/4" x 7-3/8"; 5" x 8") and edge punched cards. Since the Randomatic does not employ any metal strips or attachments on the cards and since the notch coding is not in the reading field of key punched or magnetic cards, the system is compatible with most other card processing systems.

The system is of modular construction. Each card tray holds up to 1500 cards (or fiche) and any number of trays may be operated from a single keyboard. The standard Randomatic coding consists of six characters, either alphanumeric or numeric. Up to one million codes are possible with complete distinction of selection. Systems range in size from small desk top models to large models about the size of an executive desk (see Figure 12). The equipment functions on 115 VAC, 60 cycle power. Prices range from $2500 to $14,375 depending on size. Additional features are available at extra cost.

Kodak Miracode System. This system consists of a cartridge file, electronic keyboard and interrogation unit, and a Recordak Lodestar Reader-Printer (Model PEK, PEK-1).

The cartridge is retrieved manually and inserted into the reader-printer. The system makes use of an optical code which is photographed on the film adjacent to the document images. One or more keyboards may be required

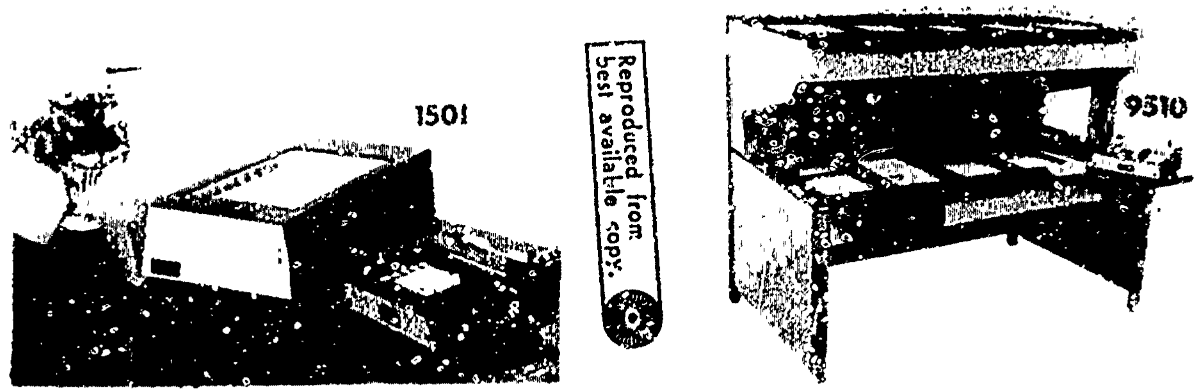

Figure 12. Randomatic Data Systems, Inc., systems range from small desk top models to large models about the size of an executive desk.

depending upon the desired depth of search capability. In addition to searching for and displaying requested images, the system will automatically scan the entire roll of film and count the number of items which correspond to one or more descriptors or classes of data.

In this system, as contrasted to the 3M Page Search below, the optical coding requires film space. Therefore, as the depth of coding is increased there is less space for document images. Since both of these systems require manual retrieval and insertion of the cartridge, their relative advantage depends, in part, upon how much search capability one desires as opposed to document image capacity per cartridge.

3M Company, Model 400 Page Search Reader-Printer. This unit is shown in Figure 13. It accepts film (roll) cartridges which are manually retrieved from a file and inserted into the machine. Electronic logic circuitry responds to blip-coded 16mm film and will find and display any one of up to 10,000 images in a few seconds. To have a document image displayed and/or printed, one need only enter the proper code number on the keyboard provided.

Dimensions of the unit are: height, 28.5"; width, 17.5"; and depth 22.75". Weight is approximately 140 lbs. It operates on 90-130 volts, 10 amps, single phase, 60 cycle power.

Fully Automatic Systems

A fully automatic system is considered one in which the storage element (cartridge, cassette, etc.) is automatically retrieved and from the element, the desired document image is displayed and printed on request.

Mosler 410. A simplified flow diagram of the Mosler 410 Information System is shown in Figure 14. As may be seen, the system features keyboard access to a central file of microfiche and/or aperture card cartridges. In

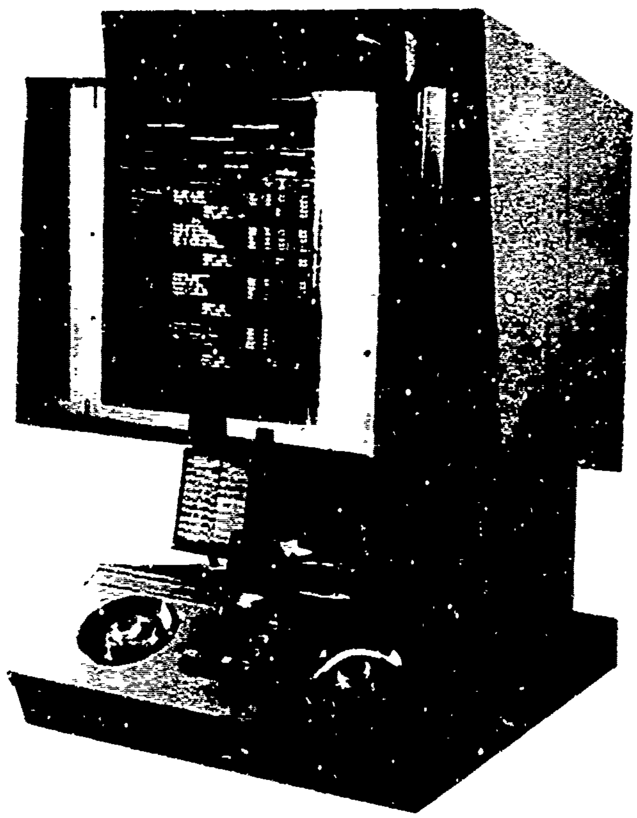

Figure 13. 3M Company, Model 400 Page Search Reader-Printer.

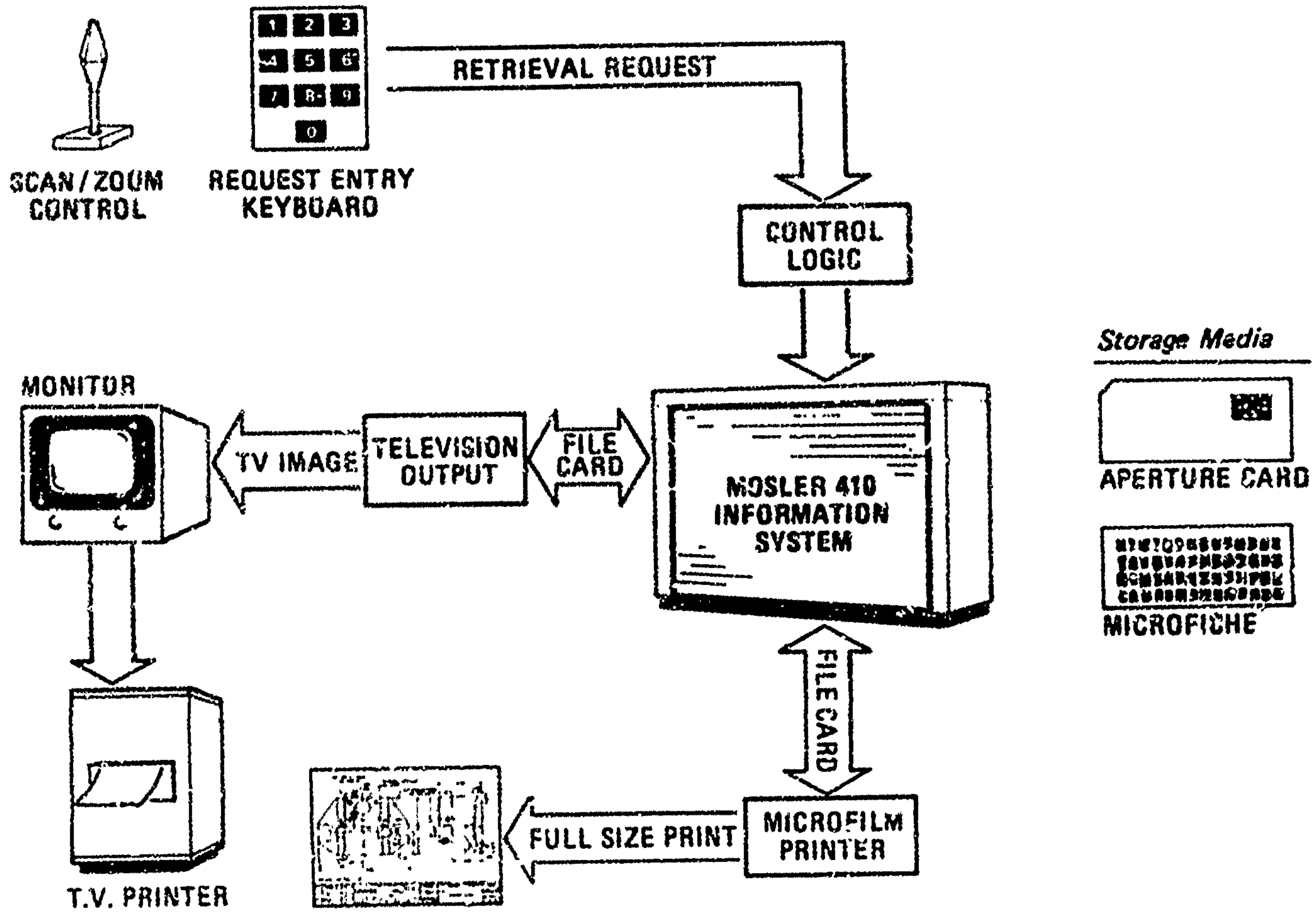

Figure 14. Simplified flow diagram of the Mosler 410 Information System.

response to a keyboard entry, the proper cartridge is automatically retrieved from its storage module and transferred to a card/fiche selector unit. The card is selected and presented to a video camera. The image is displayed on a remote television monitor. A video printer will produce a copy of the image on request of the user.

Alternatively, the system will deliver to the control console an individual card/fiche or an entire cartridge for updating or other purposes. A card punch unit is provided as part of the system for file maintenance.

A detailed description of this system is beyond the scope of this report. However, several additional factors may be noted.

The Mosler 410, in its various configurations, automatically stores, retrieves, duplicates, transmits, and copies alphanumerics, text, and graphics. Any document in the system can be retrieved in less than ten seconds, and several users may have simultaneous access to different documents. Up to 200,000 cards may be stored in and retrieved from a 410 storage module. Since microfilm is the primary method of preparing documents for infiling, a single storage unit may contain from 200,000 to 11,000,000 documents (depending on reduction ratio and document size) on 3-1/4" x 7-3/8" aperture cards on microfiche. As many as five storage modules can be operated under a unified system under common control. The system accommodates existing standard aperture cards, and these cards may be freely intermixed with microfiche within the information store. Requests may be entered into the system from keyboards either in the file area or remote from it, and may communicate with the system either directly or through any of a number of third generation computer systems. Once infiled into a 410 system, all handling of the cards is entirely automatic. The cards are held secure within the system, and are made physically available only to file-maintenance operators through controlled access stations for add, purge, and update functions. Information from these secure cards, however, is made freely available to information users either as high-resolution paper or

microfilm copies, or as remote television displays. Depending upon its configuration, system cost ranges from $100,000 to $200,000.

Sanders-Diebold, Inc. This company also manufactures an automatic retrieval system employing video dissemination.

Computer Output Microfilm (COM) Systems

Modern technology makes it possible to convert computer output (online or via tapes) to microform images. This function frees the computer from printing press jobs and outputs the data in the easily handleable medium of microfilm.

DatagraphiX, Inc. Figure 15 shows the basic components of a COM system. Computer output is fed directly (or via tapes) into a micromatic recorder for photographing. Within the recorder, the digital information is displayed on a high resolution oscilloscope type display and photographed at a transfer rate of up to 120,000 characters per second. The film is then transferred to the next unit for processing. After processing, the film serves as a master for use in a hardcopy printer or can be duplicated for use in microfilm and fiche inquiry stations.

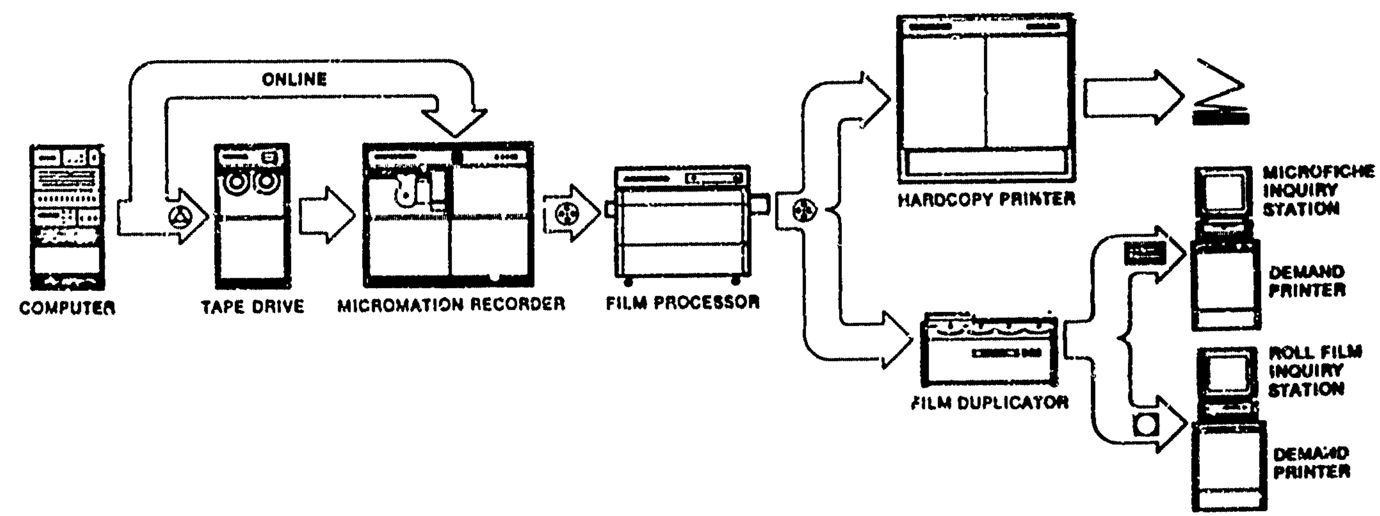

Figure 15. Basic components of a COM system.

PART III

POTENTIAL SHIPBOARD APPLICATIONS

The purpose of this section is to provide an overview of shipboard information processing activities with regard to potential applications for microform systems and equipment

Two primary factors which determine the kind of information required by a ship are the type of ship and its mission. Each ship has a general mission corresponding to the design of the ship and it has assigned primary and secondary mission areas. These mission areas are activities which fall within the ship's design capability.

Table 23 illustrates the kind of information and its current format used by different types of ships. It may be noted that the majority of material is in the form of paper, either as bound publications or sheets. The volume of a given type of information on a ship at any time depends on the type of ship and its mission. For example, a small craft may have only a few maps aboard while a carrier may have as much as 16 tons of maps.

Table 24 shows the distribution of information according to representative types of combatant ships and the major departments, divisions, or functions. The ship types selected are illustrative only. There are many different ships within a given type; however, insofar as potential microform applications are concerned, the information requirements would be quite similar. Also, no patrol or service craft have been addressed in this report as they are specifically dedicated, and as far as the present orientation is concerned, their inclusion would not reveal any new areas of application.

Table 25 shows the information distribution for non-combatant type ships. It may be seen that certain categories of information are common to different types of ships but exist in varying amount and degrees of use. The

TABLE 23

Types of Information and Current Format
Used by Ships

Types of Information	Current Format
1. Maps	Paper (sheets)
2. Basic Encyclopedias	Bound hard copy (BHC)
3. National Intelligence Surveys	BHC, microfiche
4. Photo-interpretation Keys	BHC
5. Intelligence Publications	BHC
6. Country and Area Studies	BHC
7. Assigned Targets of War	Film, BHC
8. Operations Plans	Paper documents
9. Characteristics and Performance Handbooks	BHC
10. Air Target Materiel Program	BHC
11. Training Materials	BHC, paper, miscellaneous
12. Ships Publications	BHC
13. Photos	Photos (paper)
14. Charts and Overlays	Paper, acetate, plastic
15. Weapons Manuals	BHC
16. Operating Manuals	BHC
17. Technical/Maintenance Manuals	BHC
18. Communication Publications (Coding/Operating/Repair)	BHC
19. Message Files	Paper documents
20. Registered Publications (RPS)	BHC
21. Ordnance Characteristics	Paper sheets (loose leaf)
22. Special Information	Paper, miscellaneous
23. Damage Control Information	BHC, paper, plastic control sheets
24. Correspondence Files	Paper sheets (in folders)
25. Report Files	Paper sheets (in folders)
26. COMTACT Publications	BHC

TABLE 23 (cont.)

Types of Information and Current Format
Used by Ships

Types of Information	Current Format
27. Personnel Records	Paper (in folders)
28. Medical Records	Paper (in folders)
29. Internal Command Correspondence Files	Paper (in folders)
30. COSAL	Computer punch cards or paper listings
31. NAVSUP Manuals	BHC
32. NAVCOM Manuals	BHC
33. Supply Instructions	BHC
34. Fleet Commander's Publications	BHC
35. FISSG	Paper (listings)
36. NMDL	Paper (listings)

TABLE 24*

COMBATANT SHIPS (Warships)

Type of Ship	General Mission	Representative Ship Functions: Intelligence	Combat Inform. Center (CIC)	Communications	Deck Operations	Weapons/ Gunnery/ Ordnance	Engineering	Administration	Logistical Support
Carrier (CV)	Support and operate aircraft and act in support of other forces.	1-13	1 (5) (9) 11 (13) 14-17	12 18 19 20 26	12 16 17 23	12 15 16 17 21 22	12 16 17 22 23	12 24-29	30-36
Cruiser (CG)	Operate independently or with other forces against air and surface threats.	1-13	1 (5) (9) 11-17	12 18 19 20 26	12 16 17 23	12 15 16 17 21 22	12 16 17 22 23	12 24-29	30-36
Frigate (DL)	Operate independently or with other forces against air, surface, or submarine targets. Functions as control center.	1 (3) 5 (6) (7) 8 9 11 12 13	1 (5) (9) 11 12 (13) 14-17	12 18 19 20 26	12 16 17 23	12 15 16 17 21 22	12 16 17 22 23	12 24-29	30-36

*Cell entry numbers refer to categories listed in Tables 23 and 26.

TABLE 24 (cont.)

COMBATANT SHIPS (Warships)

Type of Ship	General Mission	Representative Ship Functions							
		Intelligence	Combat Inform. Center (CIC)	Communications	Deck Operations	Weapons/ Gunnery/ Ordnance	Engineering	Administration	Logistical Support
Destroyer (DD)	Conduct offensive operations with other forces and protect support forces.	1 (3) 5 (6) (7) 8 9 11-13	1 (5) (9) 11 12 (13) 14-17	12 18 19 20 26	12 16 17 23	12 15 16 17 21 22	12 16 17 22 23	12 24-29	30-36
Escort (DE)	Screen support forces. Operate offensively against submarines.	1 (3) 5 (6) (7) 8 9 11-13	1 (5) (9) 11 12 (13) 14-17	12 18 19 20 26	12 16 17 23	12 15 16 17 21 22	12 16 17 22 23	12 24-29	30-36
Small Combatant	Perform offensive and defensive roles as directed.	1 (3) 5 (6) (7) 8 9 11-13	1 (5) (9) 11 12 (13) 14-17	12 18 19 20 26	12 16 17 23	12 15 16 17 21 22	12 16 17 22 23	12 24-29	30-36
Command (LCC)	Command ship for amphibious operations.	1 5 8 11 12	1 8 12 14 16 17	12 18 19 20 26	12 16 17 23		12 16 17 22 23	12 24-29	30-36

TABLE 24 (cont.)

COMBATANT SHIPS (Warships)

Type of Ship	General Mission	Representative Ship Functions: Intelligence	Combat Inform. Center (CIC)	Communications	Deck Operations	Weapons/ Gunnery/ Ordnance	Engineering	Administration	Logistical Support
Assault Ship-General Purpose (LHA)	To embark, deploy, and land elements of marine landing force by various means.	(5) 8 12 14 16 17		12 18 19 20 26	12 15 16 17 21 22 23		12 16 17 22 23	12 24-29	30-36
Cargo Ship (LKA)	To transport and land combat equipment, material, and personnel.	(5) 8 12 14 16 17		12 18 19 20 26	12 15-17 21-23		12 16 17 22 23	12 24-29	30-36
Transport (LPA)	To transport land troops, supplies, and equipment.	(5) 8 12 14 16 17		12 18 19 20 26	12 15-17 21-23		12 16 17 22 23	12 24-29	30-36
Dock Landing Ship (LPD)	To transport troops and equipment and supplies by landing craft and amphibious vehicles with helicopter augmentation.	(5) 8 12 14 16 17		12 18 19 20 26	12 15-17 21-23		12 16 17 22 23	12 24-29	30-36

TABLE 24 (cont.)

COMBATANT SHIPS (Warships)

<table>
<tr><th rowspan="2">Type of Ship</th><th rowspan="2">General Mission</th><th colspan="8">Representative Ship Functions</th></tr>
<tr><th>Intelligence</th><th>Combat Inform. Center (CIC)</th><th>Communications</th><th>Deck Operations</th><th>Weapons/ Gunnery/ Ordnance</th><th>Engineering</th><th>Administration</th><th>Logistical Support</th></tr>
<tr><td>Assault Ship --Helicopters (LPH)</td><td>To transport and land troops and essential equipment by embarked transport helicopters.</td><td>1-13</td><td>1
(5)
(9)
11
(13)
14-17</td><td>12
18
19
20
26</td><td>12
16
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23</td><td>12
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16
17
21
22</td><td>12
16
17
22
23</td><td>12
24-29</td><td>30-36</td></tr>
<tr><td>Landing Ship (LS)</td><td>To transport and land personnel, supplies, and equipment during amphibious assault.</td><td colspan="2">5
8
12
14
16
17</td><td>12
18
19
20
26</td><td colspan="2">12
15
16
17
21
22
23</td><td>12
16
17
22
23</td><td>12
24-29</td><td>30-36</td></tr>
<tr><td>Mine Sweeper, Coastal (MSC)</td><td>To locate and/or sweep or neutralize sea mines.</td><td colspan="2">8
11
12
14-17</td><td>12
18
19
20
26</td><td colspan="2">12
15
16
17
21-23</td><td>12
16
17
22
23</td><td>12
24
25
27-29</td><td>12
31-33</td></tr>
<tr><td>Mine Sweeper, Ocean (MSO)</td><td>To locate and/or seeep or neutralize sea mines.</td><td colspan="2">8
11
12
14-17</td><td>12
18
19
20
26</td><td colspan="2">12
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16
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21-23</td><td>12
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24
25
27-29</td><td>12
31-33</td></tr>
</table>

TABLE 25 **

NON-COMBATANT SHIPS (Auxilliary Ships)

Type of Ship	General Mission	Representative Ship Functions: Intelligence	Combat Inform. Center (CIC)	Communications	Deck Operations	Weapons/ Gunnery/ Ordnance	Engineering	Administration	Logistical Support
Tender (AD)	To repair and support destroyer type ships	12 14 19 20 26			12 23 16 17 A*		12 16 17 23	12 24-29	12 30-36
Ammunition Ship (AE)	To deliver ammunition to the fleet at sea.	12 14 19 20 26			11 12 23		12 16 17 23	12 24-29	12 30-36 B*
Stores Ship (AF)	To deliver provisions to fleet at sea.	12 14 19 20 26			11 12 23		12 16 17 23	12 24-29	12 30-36 B*
Miscellaneous Auxilliary (AG)	Missions and tasks are specific to each ship.	12 14 19 20 26			11 12 23		12 16 17 23	12 24-29	12 30-36 B*

A* Repair division; large volume of manuals.

B* High volume of accounting and record keeping.

** Cell entry numbers refer to categories listed in Tables 23 and 26.

TABLE 25 (cont.)

NON-COMBATANT SHIPS (Auxilliary Ships)

Type of Ship	General Mission	Representative Ship Functions							
		Intelligence	Combat Inform. Center (CIC)	Communications	Deck Operations	Weapons/ Gunnery/ Ordnance	Engineering	Administration	Logistical Support
Missile Range Instrumentation Ship (AGM)	To provide support during missile shots and manned space flights.	12, 14, 19 20, 26 A* 16, 17 B*		13 18 19 20 26	(minimal)		12 16 17 C*	12 24-29	30-36 D*
Cargo Ship (AK)	To transport dry cargo for the Armed Forces.	(negligible) 12, 14, 19, 20, 26			11 12 16 17 23 E*	(negligible)	12 16 17 23	12 24-29 (minimal)	30-36 F*
Oiler (AO)	To replenish petroleum products for fleet at sea.	(negligible) 12, 14, 19, 20, 26			11 12 16 17 23 E*	(negligible)	12 16 17 23	12 24-29 (minimal)	30-36 F*

A* Negligible.

B* Large volume of technical manuals in support of electronic gear.

C* Large volume of technical manuals.

D* Specialized with respect to mission.

E* Deck handling.

F* High volume of record keeping.

TABLE 25 (cont.)
NON-COMBATANT SHIPS (Auxilliary Ships)

Type of Ships	General Mission	Representative Ship Functions: Intelligence	Combat Inform. Center (CIC)	Communications	Deck Operations	Weapons/ Gunnery/ Ordnance	Engineering	Administration	Logistical Support
Transport (AP)	To transport troops, supplies, and equipment.	(negligible) 12, 14, 18, 19, 20, 26			11 12 16 17 23 A*	(negligible)	12 16 17 23	12 24-29 (minimal)	30-36 B*
Repair Ship (AR)	To furnish repair personnel, facilities and support to various types of ships.	(negligible) 12, 14, 19, 20, 26 (low volume)			11 12 16 17 23 C*	(negligible)	12 16 17 23	12 24-29 (minimal)	30-36 B*
Tug (AT)	To tow ships and craft.	(negligible) 19 (routine/minimal)			16 17	(negligible)	12 16 17	12 24-29 (low vol.)	30-36 (minimal)

A* Deck handling.

B* High volume of record keeping.

C* Low volume.

information may be required for normal operations or it may be provided or acquired on an ad hoc basis in accordance with a given mission or zone of operation.

Depending upon the nature of the information involved, it will exist at differing levels of security classification, in various formats, and will be associated with differing modes of acquisition, storage, retrieval, and dissemination.

The amenability of information to micromation (the conversion to and use of microform systems) depends upon a variety of factors: (1) how the information is used; (2) what volume of information is involved; (3) file activity patterns--frequency of retrieval; (4) useful life of the information; (5) requirements for information change and updating; (6) security and anticompromise requirements; (7) equipment cost; and (8) others.

The above considerations will determine the type of microform format and system which is most appropriate. The key issue is whether micromation will substantially improve operating efficiency and information security at an acceptable level of cost. The security of information in this regard includes protection of classified documents and prevention of loss or misfiling of unclassified materials.

As seen in Part II of this report, microform encompasses a wide range of capability from the small, portable viewer which may be used by a technician to the fully automatic storage and retrieval system employing a large central file and video dissemination of information. Between these extremes, there are many intermediate systems of varying capacity and flexibility. At present, microform is in use on various ships but not to the extent that it makes full use of available technology.

Table 26 indicates a suitable microform medium for each of the types of information and formats listed in Table 23.

TABLE 26

Suitable Microform for Various Types of Information
Used Aboard Ships

Types of Information	Microform Suitability
1. Maps	70mm microfiche (or roll)
2. Basic Encyclopedias	16mm microfiche (or roll)
3. National Intelligence Surveys	Already on 16mm fiche
4. Photo-Interpretation Keys	35mm aperture cards
5. Intelligence Publications	16mm microfiche (or roll)
6. Country and Area Studies	16mm microfiche (or roll)
7. Assigned Targets of War	Available on 35mm aperture cards
8. Operations Plans	16mm microfiche (or roll)
9. Characteristics and Performance Handbooks	16mm microfiche (or roll)
10. Air Target Materiel Program	16mm microfiche (or roll)
11. Training Materials	16mm microfiche (or roll)
12. Ships Publications	16mm microfiche (or roll)
13. Photos	35mm or 16mm aperture cards (depending on size of original)
14. Charts and Overlays	70mm microfiche
15. Weapons Manuals	16mm microfiche (or roll)
16. Operating Manuals	16mm microfiche (or roll)
17. Technical/Maintenance Manuals	16mm microfiche (or roll)
18. Communication Publications (Coding/Operation/Repair)	16mm microfiche (or roll)
19. Message Files	16mm microfiche (or roll)
20. Registered Publications	16mm microfiche (or roll)
21. Ordnance Characteristics	16mm microfiche
22. Special Information	Various formats
23. Damage Control Information	35mm aperture cards
24. Correspondence Files	16mm roll film
25. Report Files	16mm roll film

TABLE 26 (cont.)

Suitable Microform for Various Types of Information
Used Aboard Ships

Types of Information	Microform Suitability
26. COMTACT Publications	16mm microfiche
27. Personnel Records	16mm microfiche
28. Medical Records	16mm microfiche
29. Internal Command Correspondence Files	16mm roll film (for archival records)
30. COSAL	Computerized on CV, CG, Tender types; otherwise 16mm roll film or microfiche
31. NAVSUP Manuals	16mm roll film
32. NAVCOM Manuals	16mm roll film
33. Supply Instructions	16mm roll film
34. Fleet Commander's Publications	16mm roll film or microfiche
35. FISSG	16mm roll film or microfiche
36. NMDL	16mm roll film or microfiche

In general, the majority of microform material would be generated by a shore based installation. There would not be a great need for microfilm production capability aboard most ships. A limited capability, however, would be desirable in dealing with message and correspondence files, where information is generated internally or externally and must be stored/ retrieved during a cruise.

The majority of publications and reference manuals could go aboard in microform. This would facilitate storage, retrieval, use, and updating. Certain manuals, such as technical and maintenance manuals where the user must be mobile and browsing is necessary, would be best left as hard copy. On tenders and repair ships, however, where equipment is worked on at a specific repair station, and a video or other type of display could be permanently emplaced, microfilm would facilitate access to technical reference data and drawings.

Micromation of Intelligence and Classified Information

Because intelligence information is a vital element of command and control planning and decisions, the need for fast and efficient data handling is essential. For this reason, intelligence operations are typically at the forefront of information technology applications. At the same time, it is necessary that implementation of plans and decisions be just as efficient. In this regard, the merits of micromation need not be differentiated on the basis of the security classification of materials involved, and to do so, would be to lose sight of the systems approach necessary to determine overall operational effectiveness.

However, there are two considerations which distinguish classified information. One is the requirement for access control, the other is the need in certain circumstances for emergency destruction of the materials. These considerations have direct implications for microform applications aboard ship.

Advantages of Classified Information in Microform

Reduced Volume and Weight. With large volumes of classified hard copy manually filed and retrieved, it is often necessary to restrict an entire area to achieve the necessary protection. The use of microfilm or microfiche reduces the physical volume of material to be controlled by more than 90 percent. This alone can free precious space for other use.

Since classified information is normally kept in safes and containers of appreciable weight, further advantage is gained in conversion to microform. The savings in weight of containers may be added to that gained by eliminating the bulk paper.

File Security. Depending upon the type of system involved, physical access to the file records may be limited to one or more key individuals. The user merely views a display and in many instances would have no need for the actual documents. If required, however, hard copy can be generated in seconds at a central file or at remote stations. The hard copy may be destroyed according to standard procedures when it has served its purpose. With sophisticated systems, it is possible to video transmit information from a central file on one ship to other ships within range, reducing the need for duplicate files and risk of information compromise.

With large documents, it is difficult to determine whether one or more pages may be missing. On microfilm, the completeness of a document may be verified in seconds.

Also, access to viewing equipment, as well as the file, may be restricted providing another degree of safeguarding.

Emergency Destruct Capability. Generally speaking, it would appear that emergency destruct would be easier and faster with a small volume of microfilm or microfiche than a large volume of hard copy. Consider trying to destroy a single file drawer of microfilm as compared to the corresponding ten drawers of paper. Also, with microform, the feasibility of in-place destruction would seem to be greater.

The destruction of aperture cards, microfiche, and microfilm in its varying containers (cartridges, cassettes, spools, etc.), however, presents different problems than hard copy. Film destruction studies have been conducted by various government agencies but much of the work is classified. At present, methods for destroying film are still in the exploratory stage. Paper destruction, however, is no better off with much reliance still placed on crude pyrotechnics.

Because microform contains so much more information than paper per unit area, destruction must be more thorough. Also, manufacturers have been working for years to extend the life and durability of film, making it more difficult to destroy than many types of paper. Because of the lesser volume of film involved, and the fact that different physio-chemical methods may be applied to film, its potential value for emergency destruct procedures should be fully explored.

Rather than approaching film as another form of paper to be burned, it may be possible to develop a special type of film base, emulsion, or both for use on classified material. Intelligence information, insofar as shipboard use is concerned, may have a limited useable life span equal to the duration of a cruise or less. Therefore, it may be entirely possible to trade durability for emergency destruct efficiency.

As an alternate approach to in-place destruction of microform materials, one may readily conceive of special disposal devices to which the relatively small volume of film may be easily and quickly transferred. Such devices may be located adjacent to microform files.

The problem of film destruction requires study to identify the proper methods, materials, and devices to be employed over a wide range of operational conditions.

STUDY CONCLUSIONS AND RECOMMENDATIONS

1. The current volume and use of hard copy aboard ships would appear amenable to conversion to microform in many areas.

2. With proper study, it should be possible to justify micromation in terms of cost, operating efficiency, and increased file security.

3. Current microform technology provides an adequate range of equipment and capabilities which can be readily matched to user requirements from carrier type ships on down.

4. Microform equipment, especially readers and reader-printers, is vulnerable to the stresses associated with the shipboard environment. Such equipment must be isolated from ambient vibration or constructed internally such that ambient vibration is not amplified to the point where it noticeably degrades display images.

5. Microform viewers intended for shipboard use should have the following features:

(1) Maximum screen brightness of at least 80 ft-L;

(2) Continuous brightness adjustment control from 0 to maximum screen brightness;

(3) Non-glare type viewing screens;

(4) Focus controls which are not overly sensitive;

(5) Provision for protection of the viewing screen from extraneous light and/or glare sources such as a shield or curtain arrangement;

(6) Provision for use of a red filter for operating under red-light conditions. Brightness adjustment or installation of the filter should not require the user to view an illuminated projection lamp or other brightly illuminated element of the system;

(7) Readers to be used under red-light conditions should be light-tight, i.e., no light leaks;

(8) Controls and contours should be designed to minimize sharp edges, corners, and projections which may injure a user upon impact. Such impact could occur during high speed maneuvers or in rough water.

6. Microform affords advantages in the area of document security and anticompromise measures. Reduced bulk represents an initial advantage. Research should be conducted to determine the most efficacious method of microform emergency destruction. Such research should consider not only the destruction of standard film (e.g., polyester) but the development of special film for use with short-lived intelligence and classified materials. Also, the research should explore the potential for in-place destruction methods offered by the various microform systems.

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13. ABSTRACT

This study examines the parameters which contribute to legibility of rear-projection display systems common in the shipboard environment. The results show the manner in which the optical and physical parameters interact to affect operator reading performance. Tables derived allow for evaluation of the relative importance of each parameter and trade-offs among combinations of variables.

Currently available microform equipment and retrieval systems are summarized and discussed in relation to information used aboard various types of ships, information format and type of microform applicable to each.

Conclusions and recommendations are made concerning the adequacy of available microform equipment for shipboard use, desirable features of equipment to be used in that environment, implications of microform for increased document security, and its potential for improved anticompromise measures.

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